Rochester Center for Economic Research

State and Federal Tax Equity: Estimates Before and After the Tax Reform Act of 1986

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1991 Conference on State and Local Taxes after TRA 86

June 1, 1991 Martha's Vineyard

Revised 23 October 1991

[1]The authors are, respectively, Associate Professor of Economics, University of Rochester, and Professor of Economics and Public Policy, Carnegie-Mellon University. The authors wish to thank the Center for Public Financial Management at CMU for computational support. In particular, they wish to thank Stuart Hiser of the Center for expert programming of the various index number routines with the Center's Statistics of Income public use samples of 1985 and 1987 federal tax returns, and the simulated state tax liabilities for 1985 and 1987 provided by Elisabeth Coutts and Dan Feenberg of the National Bureau of Economic Research. Finally, we wish to thank our discussants Jim Hines and Bob Tannenwald for their comments. Bob Inman and Lee Friedman also provided some useful suggestions. Responsibility for any errors probably nonetheless rests with the authors.

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1. Introduction

The systematic characterization of the distribution of income has long interested social scientists, statisticians, and policymakers. The normative content of various statistics that summarize large amounts of information about, for example, the before or after-tax distribution of income, is often quite important in public policy debates about the wisdom of particular tax and spending programs. Indeed, the charge that a particular public policy is "regressive" carries with it significant negative connotations and the implication that such a policy should be withdrawn because it offends our shared values of what a just distribution of income should be.

How one defines and actually measures such emotive terms as "equitable," "inequitable," "progressive," and "regressive" can have a significant impact on public debate on such policies, and are often discussed as election issues.

The Department of Treasury and the Joint Committee on Taxation have, over the years, developed a microsimulation model of the tax code that is used to evaluate policy changes. This model presumes no behavioral reaction on the part of taxpayers beyond itemizing when it is tax-minimizing, and simply takes a random, stratified sample of returns through the changes in law, weights the resulting tax liability to bring the sample to national totals, and reports the results. The model is used primarily to project how revenue changes with policy. However, computations from the model have often been used to characterize the equity aspects of changes in policy. The model generates three items that are given to lawmakers for any tax proposal:

1) The number of taxpayers by income class whose tax liability increases and decreases;

2) The average dollar amount of increase or decrease by income class;

3) The change in tax burden for representative fictitious taxpayers.

These statistics are what generally appear in newspapers when tax legislation is being considered by Congress. To economists, these statistics do not accurately measure the equity aspects of the tax system that should be measured[2]:

Vertical Equity - The degree to which taxpayers with higher ability to pay in fact pay more in taxes.

Horizontal Equity - The degree to which taxpayers in identical circumstances pay the same taxes.

Over the years, a number of statistical measures of these properties of a tax system have been proposed and used.

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[2]See Musgrave and Musgrave [1989, p.223].

These include the Gini coefficient, median effective tax rates by income class, and the coefficient of variation of effective tax rates. It has become apparent that these simple measures do not capture the important horizontal and vertical aspects of taxation, and this has led to the development of more sophisticated and axiomatically justified measures.

Although tax policy is often driven by revenue or perhaps efficiency considerations, the congressional decision process makes it important to provide simple measures of the relevant equity aspects of tax legislation to policymakers.

The focus of this paper is not on the theory of such measures, which is addressed elsewhere (see Berliant and Strauss [1991] as well as a large literature, some of which can be found in the bibliography), but rather on the application of these measures to a new context, that of state finance. Full evaluation of a federal tax policy requires consideration of state taxes as well, since the total tax burden consists of federal, state and local components. State tax burdens are affected by federal tax policy in several ways. First, a state may enact explicit changes in its tax code in response to a federal policy[3]. Second, changes in federal liability can affect state liability through deductions. Third, state tax bases can depend on the definition of the federal tax base. The Tax Reform Act of 1986 provides researchers with an opportunity to examine the equity effect, both federal and state, of a major change in federal tax law. Revenue neutrality was central to this bill, while the focus was on equity. It is interesting to see what happened given the revenue constraint. In this paper, we seek to address the following questions:

1) How do state income taxes compare with federal income taxes and with each other in terms of equity?

2) What effect did the Tax Reform Act of 1986 (TRA 86) have on the equity of state income taxes, and how did this reaction compare to the change in equity at the federal level? What was the net effect of the changes at both levels of government?

3) Are the dynamics of the equity of state income taxes correlated with that of federal taxes?

We attempt to answer these questions by examining actual individual income and tax data on the federal individual income tax, and by using the results from state personal income tax calculators developed by the NBER as an adjunct to its TAXSIM federal tax calculator. The previous studies of state income taxes have relied on massive imputations (see Scott and Triest [1990]). Kern [1990] examines the impact of TRA 86 at the federal level only, using the 1984 tax model rather than actual post-reform data to project effects. The equity measures used in

[3]See Ladd [1991]

these studies do not mesh with those advocated in the theoretical literature.

To begin to answer these questions, we shall use Statistics of Income (SOI) data from 1985 and 1987. 1985 will be used as a base case, since capital gains realizations accelerated in 1986 due to the expected change in taxes (see Joint Committee on Taxation [1990]). 1987 is the most recent year for which SOI data is available. The first step is to compute equity indices for each state that has an income tax for each of the two years, as well as federal equity indices by state for each of these years. Then the indices are computed for the combined federal and state personal tax system for each state and compared with the values for the federal system alone in order to examine the marginal effects of each state personal tax system on overall equity.

Our findings are as follows. First, in both 1985 and 1987, state personal income taxes are generally less progressive and more horizontally equitable than the federal system. This probably results from lower rates and perhaps fewer deductions and exemptions in the state systems (in Pennsylvania, for example) than the federal system. Second, in moving from 1985 to 1987, state personal income tax systems generally displayed decreased progressivity and decreased horizontal equity. Also, the federal personal tax system displayed decreased progressivity and horizontal equity. The combination of the two systems displayed generally lower progressivity and lower horizontal equity scores when we compare 1987 to 1985. Last, the after tax income distribution became more unequal when we compare 1987 to 1985. Our results are consistent with those in the recent literature on income inequality and taxes in the 1980's, such as Gramlich, Kasten, and Sammartino [1991] or Michel [1991]. The main conclusions drawn from that literature are that before and after tax income inequality increased in the 1980's, and although the federal individual income tax remained progressive over this time period, its progressivity declined. We come to the same conclusions for the years 1985 and 1987, but add to these conclusions. We found that federal equity declined as well, state progressivity and equity declined, and that the net effect of the combination of federal and state tax systems is unambiguously a federal tax system in 1987 that was less progressive overall than in 1985. Our methodology differs from these other studies, in that we account for state income taxes, in that we do not account for transfers and imputations that might be made, and in that we use actual post - behavior data rather than data from earlier years that is aged. Finally, we employ a variety of measures rather than focus on one particular measure.

It is also interesting to compare our results with the literature on state income tax progressivity, a recent contribution to which is Formby and Sykes [1984]. They find, as we do, that there is a good deal of variation in the progressivity of state income taxes across states, and that the federal personal income tax tends to be more progressive than the state personal income taxes. Our ranking of the progressivity of state income taxes is in general agreement with theirs. For example, Formby and Sykes find that Maryland has a less progressive tax than many

states, and our results confirm this. Formby and Sykes examine the progressivity of the North Carolina income tax over the period 1957-1982, and find a general trend of declining progressivity. This is consistent with our result for North Carolina in 1985 and 1987, which generally displays a *decrease* in progressivity for that state, independent of the measure used. One can conclude from this that TRA 1986 had an important impact on North Carolina that was consistent with the long-term trend.

Since the emphasis of this work is on the empirical evaluation of state taxes, we omit a detailed discussion of the theory of index numbers, and merely outline some approaches that have been used.

The paper is organized as follows. In Section 2, we discuss the general literature and approaches to income and tax inequality. In Section 3, we introduce the index numbers used in our research. In Section 4, we summarize the characteristics of the data and our methodology. In Section 5, we examine how the data is characterized by the index numbers. When index numbers are computed using our data, many index numbers drawn from the literature will be included. Section 6 contains conclusions and directions for future research. Appendix I contains explicit formulae for the index numbers employed.

2. Approaches to Characterizing the Distribution of Taxes and Income

From a theoretical standpoint, index numbers describing the distribution of income or tax burdens arise from two directions. First, they can be justified as simple summary statistics to be used by policymakers in evaluating tax systems. In this sense, they are directly connected to a policymaker's preferences. A second way they can arise is by their explicit entry in agents' utility functions (that is, they summarize an externality) or in a social welfare function; see King[1983].

From a pragmatic viewpoint, the first motivation is more important. Recalling the definitions of vertical and horizontal equity given in the previous section, methods for quantifying the *degree* of vertical and horizontal equity embedded in a tax system are needed to evaluate policy changes.

Better than sixty years ago, the English economist Dalton [1925] pointed out that underlying the choice of one statistical inequality index over another (e.g., choosing the GINI coefficient of income inequality rather than the variance of income) is some notion of aggregate or social welfare that would be maximized were the index to reach its limit [say an egalitarian or equal distribution of after-tax income] as a result of deliberate social policy.

Dalton focused attention on the fact that our inference about the desirabity of specific distributional policies might be affected by the nature of the index number or summary statistic used to compare present circumstances [say, the current distribution of income] with those resulting from a specific policy.

Over the years, a number of measures of (after tax) income inequality, such as the Gini coefficient (see Appendix I for an algebraic statement) have been proposed and used. However, in the specific context of tax policy, these simple measures do not capture the notions of either vertical or horizontal equity. They capture shifts, say, between the before and after tax distributions of income, but do not account for how individuals are treated by the tax system. For example, the relative positions of an individual in the before and after tax income distributions might be quite different. The axioms or properties underlying these index numbers of income inequality have have been examined only relatively recently; see, for example, Thon [1972].

In 1948, Musgrave and Thin proposed some crude progressivity measures. These measures included the rate of change of the effective or average tax rate as income changes, the rate of change of the marginal tax rate, the elasticity of tax liability with respect to before tax income, and the elasticity of after tax income with respect to before tax income. These could be graphed over the range of before tax incomes, or averaged over this range. These measures are easily calculated for statutory taxes. However, they are hard to calculate for the empirical distribution of taxes, since there is generally considerable variance in the taxes actually paid at any income level; see for example Gouveia and Strauss [1991]. This variety of measure also takes into account statutory law and portions of tax schedules that might apply to nobody; thus, it is important to account for the characteristics of taxpayers who are actually present. Toward the end of their article, Musgrave and Thin propose a measure, the measure of effective progression, that does not suffer from these deficiencies. It is defined by one minus the before tax Gini coefficient over one minus the after tax Gini coefficient. However, the most important deficiency of all of these measures is that the value judgments underlying them are not explicit.

Next, we turn to the modern development of index numbers of vertical and horizontal equity, which is based on properties that characterize (that is, are necessarily satisfied by and are implied the use of) a particular measure.

Two approaches to this problem of how to choose the proper index number for evaluating tax and income distributions suggest themselves: 1] try to derive an index number from an aggregation rule or social welfare function which contains specific value-judgements about how society views individual incomes--we call this approach to index number construction the "welfare approach;" and 2] view an index number as a normative decision tool directly, and choose it on the basis of the plausibility of the value judgements contained in the indices directly. We call this second approach to index number construction the "direct approach." We turn first to the welfare approach.

In a fundamental paper, Atkinson[1970] argued that an index number summarizing the distribution of income should be derived from a well-defined social welfare function [SWF]. Most recent work on index numbers of

income inequality as well as poverty lines are generalizations or extensions of this line of analysis and technique of proof. An example may be found in King [1983]. Atkinson [1970] suggests that the social welfare function be of the general additively separable and symmetric form:

$$W = \sum_{i=1}^{n} U(y_i) \tag{1}$$

where y_i is income of the i'th unit, and U is a monotonic indirect utility function. The concept of equally distributed equivalent income, y_{ede}, per capita income yielding the same social welfare as the true distribution, is defined by:

$$nU(y_{ede}) = \sum_{i=1}^{n} U(y_i). \tag{2}$$

The inequality index I is defined to be the loss in social welfare, in terms of income, from having income unequally distributed, normalized by mean income. Formally, if m is mean income of the true distribution,

$$I = 1 - y_{ede} / m$$

If I is assumed to be invariant to proportional shifts in the distribution, i.e.

$$I(y_1,...,y_n) = I(ky_1,...,ky_n)$$

for $k > 0$, then using some mathematics derived in the theory of risk aversion,

$$I = 1 - [\sum_{i=1}^{n} y_i^{1-t}/m]^{1/1-t}. \tag{3}$$

The parameter t here represents the degree of inequality aversion, analogous to risk aversion in the theory of uncertainty.

While the derivation of various indices of vertical and horizontal equity from social welfare functions has been a prevalent form of theoretical rationale for particular equity measures[4], this line of research suffers from certain limitations. What does a social welfare function do? It ranks states of an economy. What does an inequality index do? It ranks states of the economy. What is the difference? What properties do we want each to have? If

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[4]Blackorby and Donaldson [1978, 1980] proved that the relationship between homothetic social welfare functions and inequality indices is one-to-one, although under their framework, ordinally equivalent indices do not always lead to ordinally equivalent social welfare functions. A general procedure has recently been proposed by Ebert [1987]. A second ordering, through which the trade-off between the inequality of an income distribution and its mean income is determined, is postulated. When this order is combined with an inequality ordering, the two orderings generate a social welfare function and vice versa.

Lin [1989] has examined the relationship between revenue, tax systems, and index numbers under the welfare approach. If the revenue generated by a certain tax system increases, does progressivity (as measured by a particular index number) increase? If so, then the tax system is said to be *progressive effective* with respect to the inequality measure. In this way, relations between index numbers, tax systems, and social welfare functions were established.

assumptions are imposed on the social welfare function, why should not the same assumptions be imposed on the index number? For example, the social welfare function of Atkinson is required to be additively separable, but the inequality index I is not additively separable in incomes. Also, the inequality index I is assumed to be homogeneous of degree zero, but the social welfare function does not have this property. The application of subsequent assumptions on the index number may reflect inconsistencies between fundamental value judgements being entertained about the social welfare function and the index number. Furthermore, since the derivation of this type of index number requires the inversion of a utility function, they are inherently single-variable in nature. This is a limitation if one wishes to characterize social welfare in terms of several variables, such as incomes and effective tax rates or incomes and tax liabilities.

A number of these disadvantages may be overcome if one views index numbers directly as a social welfare function, and simply chooses an index number on the basis of its inherent plausibility.[5] Below, a broad class of index numbers based on the *relative* position of all pairs of incomes in society is developed. The underlying separability assumptions are weaker than those of King [1983] and Atkinson [1970], and as such are inherently more attractive. In the next section, we shall describe the intuition behind these index numbers. For a theoretical development and further applications, we refer to Berliant and Strauss [1991]. Appendix I contains the formal definitions of many index numbers, all of which are used in the empirical applications below.

The literature on vertical equity is huge and growing, so it would be futile to try to give a complete survey in the limited space here. We can only say that there are many approaches to this measurement problem, and that many measures are yet to be justified by axiomatic characterizations. References in other strands of the literature include Kakwani [1977] and Suits [1977].

The literature on horizontal equity is more recent but is rapidly developing. Feldstein [1976] ignited interest in this area by discussing its importance in the context of tax reform. He asserted in this paper (p. 83) that the classic definition is related to the principle that the ordering of individuals by utility level should not be changed by a tax system. This led researchers to consider measures of rank reversals in utility or income to be measures of horizontal inequity. Atkinson [1980], Plotnick [1981, 1982], and King [1983] followed up on this line of reserch. For examples demonstrating that such measures are unrelated to the classical concept of horizontal equity defined above, see Berliant and Strauss [1985]. Recent contributions to this literature include Kaplow [1989], Musgrave [1990], and Jenkins [1988]. Currently, there is much debate about the definition of horizontal equity, and how it might be

[5]Under this second approach, population decomposibility is the axiom employed most frequently; see for example Shorrocks [1980, 1984]. Recently, Shorrocks and Foster [1987] have shown that transfer sensitive Pigou-Dalton indices agree on the pairwise inequality ranking of one income distribution obtained from another using favorable composite transfers.

made operational. We prefer the classic definition, and direct axioms or properties that characterize the index numbers.

3. Operational Measures of Vertical and Horizontal Equity

We provide below operationalizations of the traditional concepts of horizontal and vertical equity. This is achieved in two steps. First, index numbers based on the equity concepts are developed. Second, they are applied along with other index numbers found in the literature to annual data on Federal individual income tax returns for the years 1985 and 1987, where state taxes are found using the NBER state personal income tax calculators.

3.1. Classifications of Progressivity and Horizontal Equity

Two prefatory remarks are in order. First, we shall use economic income as a proxy for individual welfare. This is equivalent to the use of an indirect utility function, and is standard in the literature. Second, we take as given a partition of the economic income distribution into cells of "equals" for the purpose of separating horizontal and vertical comparisons. We also take as given a partition of the set of effective tax rates into cells, which is used to distinguish "similar" effective tax rates for proportional comparisons. Clearly the index number values depend on the precise nature of these partitions, but the empirical ordering of tax systems generated by the index numbers is generally independent of these partitions. Such partitions are necessary to ensure that the empirical implementation of these index numbers is computationally tractable.

To describe the vertical characteristics of the tax system, we follow Wertz [1975, 1978] and partition comparisons between taxpayers into three groups: the fraction of pairs of taxpayers whose tax liability is progressively distributed, the fraction of pairs of taxpayers whose tax liability is proportionately distributed, and the fraction of pairs of taxpayers whose tax liability is regressively distributed. We shall construct the measures so that they sum to 1. A comparison of taxpayers shows progressivity when both the income and effective tax rate of one taxpayer are greater than the income and effective tax rate of the other taxpayer. Proportionality is said to occur when the incomes of two taxpayers are different, but the effective tax rates are the same. Finally, regressivity is said to occur when one taxpayer has a larger income but a lower effective tax rate than the other taxpayer in the pairwise comparison. Counting the number of paired comparisons that are progressive and dividing by the total number of paired comparisons between taxpayers with different incomes (the vertical comparisons) yields the unweighted progressive index. Similar computations yield the unweighted proportional and regressive index numbers.

Table 3-1 provides a summary of the classifications of these static comparisons between pairs of taxpayers.

To ascertain the *extent* to which taxes are distributed progressively, proportionately, and regressively, we take into

Table 3-1: Definition of Static and Dynamic Berliant-Strauss Index Numbers

STATIC Comparison		DYNAMIC: More Prog	DYNAMIC: No Change	DYNAMIC: More Regr
Progressive	$Y_1 > Y_2$ $t_1 > t_2$	$\frac{t'_1}{t_1} > \frac{t'_2}{t_2}$	$\frac{t'_1}{t_1} = \frac{t'_2}{t_2}$	$\frac{t'_1}{t_1} < \frac{t'_2}{t_2}$
Proportional	$Y_1 \neq Y_2$ $t_1 = t_2$	$t'_1 < t'_2$ for $Y_1 < Y_2$	$\frac{t'_1}{t_1} = \frac{t'_2}{t_2}$	$t'_1 < t'_2$ for $Y_1 > Y_2$
Regressive	$Y_1 < Y_2$ $t_1 > t_2$	$\frac{t'_1}{t_1} < \frac{t'_2}{t_2}$	$\frac{t'_1}{t_1} = \frac{t'_2}{t_2}$	$\frac{t'_1}{t_1} > \frac{t'_2}{t_2}$

NOTE: Y is income, person 1,2;
t is effective tax rate in period 1 (initial period); and
t' is effective tax rate in period 2 (after tax changes).

account not only the *number* of occurrences of each type of comparison, but also the *degree* of income and effective tax rate disparities. Our subjective judgement is that it matters when scoring such comparisons whether taxpayer A with an effective tax rate of 28% and taxpayer B with an effective tax rate of 20% have similar or very different incomes. Thus the actual measurement involves the weighting of each comparison count by the absolute difference in income of each pair of taxpayers.

Similar considerations argue for taking into account the *extent* of differences in effective tax rates. That is, it seems to matter, if taxpayer A has an income twice that of taxpayer B, just how similar (or different) the effective tax rates are for the two taxpayers. For example, should A have an income of $30,000 and B have an income of $15,000, the 'progressiveness' of the tax system would seem to differ if in the first instance the respective effective tax rates were 28% and 20% while in the second instance effective tax rates of 32% and 18%. Clearly, the former would seem to be *less* progressive than the latter.

To account for such differences in effective tax rates, we weight the comparisons by the *ratio* of effective tax rates rather than the *differences* in effective tax rates. We do this for several reasons. First, using the ratio differentiates more effectively between a pair of effective tax rates that are close to each other nominally but not relatively. A pair of effective tax rates of 10% and 14% would seem to be much more disparate than a pair of effective tax rates of 46% and 50%. While the *differences* are both 4%, the former pair of tax rates clearly displays more disparity. Second, using the ratio of rates deals with proportional comparisons when forming the weights for each comparison operation. If one were to form a weight based on the difference in effective tax rates, the weight would be zero, while by using the *ratio* the weight becomes unity. Third, to deal with a comparison between a positive and a negative tax rate, we take a ratio of the tax rate *class ranks* (or subscripts) rather that the ratio of the average tax rates in the classes themselves. To be consistent, we also use the ratio of class ranks in comparisons involving two positive tax rates as well as any comparison involving a zero tax rate.

The weighted vertical index numbers are formed as follows. For each progressive comparison, weight by the difference in incomes and the ratio of effective tax rates, and sum over progressive comparisons. Repeat this procedure for both regressive and proportional comparisons as well. Divide each of these sums by the total weighted sum over all vertical comparisons.

Horizontal equity, unlike vertical equity, does not admit of multiple classifications. Simply put, horizontal equity means either that equals are treated the same, or not. Accordingly, we shall measure the *extent* to which effective tax rates are different or are identical. Again, following Wertz [1975], we classify instances of differential effective tax rates for pairs of taxpayers with identical incomes to be instances of *inequity*, and instances of identical effective tax rates for pairs of taxpayers with identical incomes to be instances of *equity*. Dividing these counts by the total number of horizontal paired comparisons, comparisons between taxpayers deemed to be equals (operationally, in terms of income), the unweighted horizontal equity and inequity index numbers are obtained. By weighting each paired comparison by the ratio of effective tax rates in order to account for the extent of inequitable treatment by a tax system, and then performing the same calculations as for the unweighted horizontal index numbers, the weighted equity and inequity index numbers are obtained. Notice that each weighted count is divided by the sum over all horizontal comparisons of weighted counts.

The weighted horizontal and vertical measures are obtained by making all possible comparisons among pairs of taxpayers, and accumulating the weighted comparisons of each type of classification. Note that in the case of the vertical comparisons, a tax system may be said to have simultaneously progressive, regressive, and proportional components to it. This occurs because comparisons are relative, and the number of comparisons are numerous. For n individuals in an economy, there are n(n-1) total comparisons.

What we call "dynamic" index numbers are used to compare two tax systems, which we call X and Y. We assume that economic income is independent of which tax system, X or Y, is imposed. In our application below, plan X is the federal income tax system, while plan Y is the total income tax system consisting of both federal and state taxes. The question we ask is as follows. Given that both the federal and state tax systems are imposed, what is the marginal effect on equity of the state tax system? We do not seek to address questions concerning the equity effect of repealing a state tax system. Therefore, the assumption that economic income is fixed is needed. For each pair of taxpayers, these dynamic index numbers account for whether the comparison becomes more progressive, regressive or proportional under Y as opposed to X, provided that the comparison is vertical; see Table 3-1. For example, consider a comparison between two taxpayers with unequal incomes. If the ratio of the effective tax rate under plan Y to the effective tax rate under plan X is higher for the taxpayer with higher income, then this comparison is classified as more progressive. If the ratios are the same for the two taxpayers, the comparison is classified as proportional. If the ratio is higher for the taxpayer with lower income, then the comparison is classified as more regressive. The counts in each classification are totalled; no weighting is involved. Dividing each count by the total number of vertical comparisons yields the dynamic vertical index numbers.

Appendix I contains algebraic formulae for the index numbers.

3.2. Properties of the Index Numbers

What properties should index numbers have? The answer to this question depends on what one is trying to measure, and what types of cardinal assumptions one wants to make. Moreover, it is natural to inquire both whether a property is satisfied by an index as well as whether it is part of some set of (minimal) sufficient conditions for deriving an index. Most index numbers in the literature have been characterized in the sense that necessary and sufficient conditions generating them have been found. Here we concentrate on necessary conditions. Complete characterizations of our index numbers can be found in Berliant and Strauss [1991].

Index numbers pertaining to income inequality tend to be dependent only on after tax income, while index numbers pertaining to vertical and horizontal equity tend to be dependent on before and after tax income, before tax income and effective rates, or before tax income and tax liability. Thus, measures of horizontal and vertical equity have more complex ordinal and cardinal properties.

The first type of property that one might require is that the index depend only on the attributes of taxpayers that actually exist, and not on parts of the tax system that apply to nobody. This condition is satisfied by most index numbers, including ours.

Another important property one might require is that an index not change when various kinds of increasing transformations of variables are taken. For example, if every taxpayer's after tax income is increased by $1, one might require that an index number's value not change, since the relative distribution of taxpayers does not change. For index numbers of income inequality, which depend only on after tax income, such assumptions are evident. For more complex numbers that depend on more than one variable per taxpayer, the formulation of such properties is not as obvious, since there are several variables (before tax income, tax liability, effective tax rate, after tax income) on which the property might hold. (Henceforth, we refer to these variables as taxpayer attributes.) Knowledge of any two of these variables allows one to calculate the other two, so index numbers of equity can be phrased in terms of any two, but cardinality properties obviously differ depending on how the index is formulated.

In addition to these concerns, there are strong and weak cardinality properties. Strongest among these are independence with respect to any increasing (even nonlinear) transformation of any attribute for all taxpayers. Weaker is the assumption that an index is independent of any increasing linear transformation of an attribute, which implies that the index is scale - independent. Finally, the weakest assumptions are of independence with respect to certain types of increasing linear transformations of attributes, such as multiplication by a positive constant or addition of a constant. In all of these cases, it is natural to put the cells of "equal" incomes and "similar" tax rates used to define our index numbers through the same transformations as income and tax rates.

It is easy to check the properties of index numbers given an algebraic statement, so we leave to the reader the derivation of properties of index numbers listed in the appendix. Here we focus on our own index numbers. We choose to focus on before tax income and effective tax rate as the two taxpayer attributes of interest. The reason this choice is made is that it results in comparisons that can be classified, as explained previously. If instead of effective tax rates we chose to use tax liability, the classification of pairwise comparisons would not be as easy or natural. For example, a pairwise comparison between two taxpayers where one taxpayer's income and tax liability were higher than the other's only has the implication that marginal tax rates are positive; it might not be classified as progressive if the effective tax rate of the first is not higher than that of the second.

First consider the unweighted index numbers (of all varieties). These index numbers depend only upon classifications of comparisons, and not on the actual values of the attributes involved. Thus, it is easy to verify that these index numbers are independent of increasing (even nonlinear and discontinuous) transfomations of each of the attributes separately. For the static index numbers, this means transformations of the before tax income scale and the effective rate scale. For dynamic index numbers, this means transformations of the before tax income scale and the ratio of plan Y to plan X effective rate scale (which, in fact, can be interpretted as transformations of the plan X and plan Y scales separately).

Now consider the weighted index numbers. For *given* effective rates, they are immune to increasing linear transformations in before tax income, but not to nonlinear transformations. They are also immune to multiplication of the effective rate scale by a positive constant, but not to addition of a constant or nonlinear transformations. In other words, the weighted measures are more cardinal than the unweighted measures. Does this make sense? The answer lies in the intuition given in the previous subsection. If we want to distinguish between comparisons of taxpayers with effective rates of 10% and 14% on the one hand, and 50% and 46% on the other, independence with respect to addition of constants (36, in this case) will not be satisfied. In other words, stronger assumptions of independence with respect to transformations are not always desirable, and are not an end in themselves.

There are many other types of axioms that might be placed on index numbers. For example, population decomposability requires that an index be additive across populations. As can easily be verified, this axiom is satisfied by many after tax income inequality measures, but not by the Gini coefficient nor any of the multivariate index numbers commonly used. Finally, one can check to see the effect on an index if the population is "cloned" so that each taxpayer is represented by two with the same attributes as the original taxpayer. Our vertical index numbers are immune to such an operation, while our horizontal numbers are not.

Many other properties of index numbers have been examined in the literature, and some index numbers, such as the Gini coefficient, possess multiple characterizations in terms of axioms.

We refer to Berliant and Strauss [1991] for characterizations of our index numbers in terms of axioms.

Kiefer [1984] tries to provide a taxonomy for sorting index numbers by their properties, narrowing down the class of acceptable index numbers to his own (among those he considers), which he modestly calls K. Most important in this taxonomy is the property that an index *should not* be invariant to multiplication of all effective tax rates by a constant. The arguments for this property are, of course, quite subjective. One could also assert that shifting the pre-tax income distribution by adding a constant to all incomes should yield the same value of the index, since neither the relative pre-tax income distribution nor tax liabilities change with this shift. It is easy to verify that Kiefer's index does not satisfy this property. The point is that there is an infinity of ways to classify index numbers, an infinity of properties (desirable or not) that they might satisfy, as well as an infinity of ways to characterize each index.

Differences between axioms underlying index numbers tend to be less relevant from the standpoint of empiricism, since the index numbers tend to be highly correlated and tend to reflect common trends. This was exposed in our earlier work, and will be discussed again in Section 5 below.

4. Data Sources and Limitations

The data used to measure the vertical and horizontal equity of the U.S. Federal individual income taxes are from publicly available anonymous samples of individual income tax returns created annually by the Statistics of Income Division (SOI) of the Internal Revenue Service, and provided periodically to the National Archives for sale as public use tapes. These data are used by the Internal Revenue Service in their annual publication *Statistics of Income: Individual Income Tax Returns*. This file is typically augmented with more high income returns than made available to the public, and provided to the Office of Tax Analysis (OTA), U.S. Treasury Department and Joint Committee on Taxation, U.S. Congress, to be used in conjunction with the Department's microsimulation model of the Federal individual income tax. (This model is used to project the revenue changes from tax reform proposals.) The OTA file is frequently modified further by the addition of imputations for data not contained on the various Federal individual income tax returns, and is reweighted to allow the data to be used to *project* income levels to future time periods.

As is well known, information on the tax position of individuals and families is generally not available from such data sources as the *Current Population Survey* or *CPS*. The *CPS* contains much richer information on transfer income to low income units, and uses a household unit of measurement which differs from that used to administer the Internal Revenue Code. The SOI files do not have information about low income individuals as many are not required to file and are not in the tax system, and thus these files have certain limitations.

Both the SOI and *CPS* fail to reflect various types of nonmarket income captured in the national income and product accounts. Personal income, as defined in the national income and product accounts, is substantially broader than adjusted gross income, total money income, or the concept of economic income we are able to construct from the available data files. Our income concepts do not capture, for example, interest on state and local bonds, which is tax exempt for federal tax purposes and therefore not reported on the federal tax forms.

Our economic income concept includes wages and salaries, interest and dividend income without regard to the dividend exclusion, the various types of business income from farming, sole proprietorships, rents, and royalties, long and short-term capital gains without regard to any exclusions, gains from installment sales, and all reported pension income. Table 4-1 displays the components of economic income for each year. For each year we have sought to use as broad a definition of economic income as permitted by the data collected by the tax administration system, but have not attempted to make imputations for exempt or excluded items from the tax system or income which might otherwise be attributable to taxpayers.

Net state personal income tax liabilities were simulated by the NBER TAXSIM model which used the 1985 and 1987 public use SOI data tapes. NBER provided to the authors the simulated net state income tax liabilities, the

state id code, federal filing status, and several other variables which permitted the unique matching of each NBER return to the original return in the 1985 and 1987 public use files maintained by the authors. The definition of economic income, net federal taxes due, and application of the various index numbers developed above exactly parallels the current and earlier research by the authors. As mentioned above, 1985 was chosen as the base year to avoid massive capital gains realizations in 1986 due to the anticipated changes in the tax code. Although the full effects of TRA 86 were not apparent in 1987 due to the phase-in of some provisions as well as the incomplete adjustment to the new law on the part of individuals, it is the most recent year for which we have data.

One problem with this reconstruction of state taxes using this data is that calculated revenue totals from the states differ substantially from actual revenue collections[6] for 1985 and 1987. There are several reasons for differences which constitute important limitations on the empirical results below:

1. The truncation of the distribution of income by state in the underlying income data which TAXSIM uses in order to prevent unlawful disclosure of high income returns by the IRS with the result that high income returns are systematically under-represented in our sample;
2. The higher tax entry point for the federal individual income tax viz a viz many state income taxes which means that low income filers for state tax purposes are not represented or are under- represented in the sample; and
3. Imprecision in the attribution of state of residence in the underlying data from the IRS. Due to the lack of interest on the part of the federal government, the individual income tax return lists the taxpayer's *mailing address* rather than the taxpayer's *place of residence.*

With better than 70,000 observations available for 1985 and 1987, calculation of the vertical equity measures would require five billion comparisons of taxpayers (recall that there are n(n-1) comparisons to make) for each year; this would clearly be too burdensome computationally. Accordingly, the data was grouped into 114 effective tax rate classes for states and 214 for the federal tax system (which has a broader spectrum of effective tax rates), and 25 economic income intervals.[7]

The effective tax rate classes utilized were .25% apart for both state and federal tax systems, and covered the negative domain as well. The income intervals were chosen each year so that each interval corresponded to 4 percent of the (weighted) number of tax returns each year. It should be emphasized that the intervals in our analysis used are quite different from those used and publicly reported by OTA. Generally, our income classes are much finer in the lower and middle ranges of the income distribution. The Treasury groupings focus attention on higher income

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[6]By "actual" we mean the observed collections for calendar years 1985 and 1987. Collections differ from liabilities for the calendar year in that they reflect payments of estimated taxes, collection of penalty and interest, withholding behavior of employers etc., while "liabilities" indicate the final, after-credits tax that was due for the calendar period.

[7]Even this reduction in the dimensionality of the computational problem requires millions of comparisons since the ij matrix has 2850 cells and needs to be compared to 2849 other cells, which implies better than 8 million comparisons. Fortunately, many cells are empty since there are not low income taxpayers with high effective tax rates, etc. The algorithm developed scans and dynamically keeps track of the relative position of non-zero cells in order to achieve computational efficiency.

taxpayers, e.g. those with income in excess of $100,000. Clearly, for distributional and general statistical analysis, using intervals that reflect the population of taxpayers is the appropriate classification scheme. A prerequisite to obtaining annual classifications by 4 percentage points is that the cumulative distribution of each file had to be calculated and recorded.

In both our previous work and this research, we have conducted experiments to check sensitivity of the results with respect to the number of income and tax rate classes. With very few exceptions, although the cardinal values of the index numbers change, their relative rankings or ordinal values of tax systems do not change.

Table 4-1: Components of Economic Income by Year

Source of Income	1985	1987
Wages	X	X
Dividends	X	X
Interest	X	X
Sole Proprietorship Income or Loss	X	X
Non-schedule D Capital Gains	X	X
Supplemental Schedule Income (form 4797)	X	X
Pensions	X	X
Farm Income or Loss	X	X
State Income Tax Refunds	X	X
Alimony Received	X	X
Capital Gains before Carryover Loss	X	X
Schedule e income	X	X
Gross Unemployment Compensation	X	X
Gross Social Security Benefits	X	X

5. Empirical Results

In 1986, the federal tax system was substantially overhauled by the elimination of any distinction between capital gains and other sources of income; the limitations placed on the amounts of active, positive income which could be offset by negative, passive losses; the phased reduction over time of the top marginal tax rate from 50% to 28/31%; and the doubling of the value of personal exemptions. Because our data ends at 1987, we can not observe the final implications of the Tax Reform Act of 1986; however, we can measure the effects of the movement to the transitional tax tables for 1987 and the broadened definitions of income.

As is well known, the states began grappling in 1985 and 1986 with what Congress finally did in the fall of 1986, and decided in various ways to keep or give back the "windfall" which the base broadening and speed up in capital gains realizations were predicted to do. Gold [1987] describes in substantial detail the range of changes that were considered in 1986 and 1987 by the states, and conjectured that, overall, state personal income taxes would become more progressive even though many states lowered their top marginal tax rates. He attributed this likely increase in progressivity to increases in personal exemptions, and the general base broadening that resulted from the passive

loss rules and elimination of the capital gains exclusion.[8]

Of interest below is how the index numbers of progressivity and horizontal equity have changed by state with these substantial changes in federal and state personal income tax law.

For both 1985 and 1987, we have constructed a series of effective tax rates which allows us to examine how state and federal individual income taxes have evolved during this period. Recall that our calculations of effective state personal income tax rates are the ratio of *simulated* state personal taxes, after credits, to economic income, while our calculations of effective federal personal income tax rates are the ratio of *reported* federal taxes net of credits to economic income.

Below, we first provide a number of tables which show the pattern of state taxes and effective tax rates for 1985 and 1987 for various parts of each state's distribution of income, and then examine with our vertical and horizontal equity measures the pattern of four effective tax rates:

- First, each state tax system is considered in isolation. In particular, effective tax rates and after-tax income distributions were computed using state taxes.
- Second, effective tax rates for the federal individual income tax in 1985 and 1987 are calculated for comparison against the effective tax rates of the state individual income taxes.
- Third, effective tax rates for the combined state and federal individual income taxes are calculated to allow us to examine the evolution of our individual income tax *system* in 1985 and 1987.
- Fourth, effective tax rates of the federal individual income tax are compared to the combined effective tax rates of the state and federal individual income taxes for 1985 and 1987 using the dynamic index numbers discussed above.

We emphasize that we are using actual post - behavior data on incomes and federal taxes rather than aged data or data processed using elasticities. By using actual federal tax return data, we are observing the results of reactions of various incentives in the federal and state tax system which causes taxpayers to alter their sources of income as well as their activities which lead to various itemized deductions. Consequently, we do not have to speculate on what such reactions might be or resort to statistical procedures to age the data to post - TRA86 periods. On the other hand, we do not have available comparable, actual state by state day on state personal income tax liabilities. However, because most personal tax planning decisions are dominated by federal tax considerations due to the higher federal tax rate structure, it seems reasonable to presume that applying in statutory state rules we are in effect observing ex post state personal income taxes that parallel in nature the actual federal liabilities.

The data we report below thus reflect the result of several sorts of processes across time: i] the changes in federal

[8]See also Tannenwald [1987] and Chernick and Reschovsky [1990] for discussions of the New England States' responses to the federal changes.

and state personal income tax statutes which reflect both fiscal and reform impulses at the federal and state level; ii] changes in the economy and the distribution of factor income which reflect secular, aggregate effects, and iii] individual and group responses to the implicit incentives contained in the state and federal tax codes which have both individual and aggregate impacts on the economy. Thus, we report the *ex post* results of these various pressures on taxes by income groups, and measure in a positive sense the vertical and horizontal equity of these fiscal systems at two points in time.

In examining state and federal effective tax rates, a subsidiary but nonetheless important issue arises due to the concurrent nature of the US fiscal system. That is, when considering taxation at two levels of government, we may wish to attribute the tax savings from the deductibility of state income taxes on federal returns. Is this savings attributable to the federal or the state income tax? This becomes more complicated by the recognition at the state level in about a dozen states of the deductibility of *federal* individual income taxes when determining state taxable income.[9] One might consider a game theoretic model or viewpoint, where the players (the state and federal governments) have (perhaps imperfect) knowledge of the other players' actions, their tax legislation and codes. Thus, the players can compute the effects or expected effects of deductibility or lack of it on their own revenues and income distributions. A government's decision to allow deductibility or not comes with knowledge or expectation of the policy implications both for its own revenues and for the corresponding distributional effects. For example, the actor knows or has expectations concerning the progressivity of its tax with and without deductibility. Each government is marginal to its own decision about whether or not to allow deductibility. This justifies attributing deductibility to the government on whose return the deduction occurs.

5.1. Some General Patterns of State and Federal Taxes: 1985 & 87

As has been described by a Gold(1987) and others, many states reduced their personal income tax rates and broadened their personal income tax bases in response to TRA86. With the results of the TAXSIM state calculators, we first examine simulated state personal tax payments by various representative taxpayers in 1985 and 1987 to ascertain if payments declined for the first quartile, median, and third quartile taxpayers.

Table 5-1 displays these estimates and indicates that for the vast bulk of states, including the large personal income tax states, personal income tax payments generally declined. The median taxpayer in Colorado, Iowa, Maine, Montana, Nebraska, New Mexico, North Dakota, Rhode Island, Utah, and West Virginia experienced personal income tax *increases* of some form, while the median taxpayers in the other states experienced personal

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[9]During the period in question, Alabama, Arizona, Iowa, Kentucky, Louisiana, Missouri, Montana, North Dakota, Oklahoma, Oregon, Rhode Island (for itemizers), Utah, and Vermont (for itemizers) have some recognition of federal individual income taxes in their personal income tax statutes.

income tax decreases (1987 compared to 1985). Taxpayers in the third quartile in *every* state except Maine and Utah experienced a tax reduction in 1987 compared to 1985. Across *all* states the median state personal income tax liability fell from $486 in 1985 to $207 in 1987, and the third quartile payment fell from $2,122 to $1,154.

Table 5-2 displays the pattern of effective state personal income tax rates. Here we see far less dramatic relative declines in effective state personal income tax rates. Overall, the median effective tax rate in 1985 fell from 1.9% to 1.3% in 1987, and the third quartile effective tax rate fell from 3.4% to 3.0%.

On the other hand, the federal effective tax rates show much more substantial declines in virtually every state. (See Table 5-3). For example, in California, the median taxpayer in 1985 faced an effective federal personal income tax rate of 10.4%, while in 1987 it dropped to 8.2%. In Illinois, the median taxpayer's effective tax rate dropped from 11.8% to 8.8%.

Finally, as might be expected, the combined federal-state effective personal income tax rates[10] showed a more moderate decline than just the federal patterns. So, in California, the median taxpayer faced a combined tax rate of 12.3% in 1985 and 9.0% in 1987. (See Table 5-4) Overall, the combined state and federal effective tax rate fell from 13.1% in 1985 to 10.4% in 1987, and the third quartile effective tax rate fell from 19.4% to 15.6%.

5.2. The Progressivity of State Individual Income Taxes:1985 & 1987

We now turn to the application of our vertical and horizontal index numbers to the 1985 and 1987 state and federal tax systems with the objective of reaching an overall, systematic conclusion about whether the state and federal personal income taxes became more or less progressive, and more or less horizontally equitable.

Table 5-5 contains the vertical and horizontal index number analysis for the weighted progressivity measure and the weighted horizontal equity measure, and indicates that the states vary widely in the levels of progressivity and horizontal equity in 1985 and 1987.

In 1985, only 23% of the paired comparisons of Tennessee's taxpayers displayed progressivity, while better than 88% of Wisconsin's taxpayers displayed progressivity. Undoubtedly, the very narrow coverage of Tennessee's tax on capital income explains the very low measured progressivity.[11] Between 1985 and 1987, the *ex post* progressivity of 37 states' personal income taxes declined. Some states closely coupled to federal law, such as North Dakota which levies a surcharge on the federal liability, experienced significant reductions in progressivity. States such as

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[10]By combined we mean the sum of the federal and state effective tax rates. The numerator in each case is the net taxes paid, after credits, and the denominator in each case is economic income as discussed in Section 4.

[11]See also the progressivity value for Connecticut.

Table 5-1: The Pattern of State Personal Income Tax Liabilities by State: 1985 & 1987

		First Quartile		Median		Third Quartile	
	ID	85 State	87 State	85 State	87 State	85 State	87 State
	All States	$0	$0	$486	$207	$2,122	$1,154
1	Alabama	$147	$58	$530	$422	$1,344	$1,110
2	Alaska	$0	$0	$0	$0	$0	$0
3	Arizona	$1	$0	$830	$641	$2,132	$1,707
4	Arkansas	$31	$0	$572	$388	$1,928	$1,387
5	California	$0	$0	$823	$357	$3,366	$1,864
6	Colorado	$90	$186	$789	$837	$2,095	$1,731
7	Connecticut	$0	$0	$4	$0	$326	$59
8	Delaware	$281	$124	$1,616	$929	$4,638	$2,351
9	DC	$366	$0	$2,586	$1,447	$5,815	$3,627
10	Florida	$0	$0	$0	$0	$0	$0
11	Georgia	$166	$79	$1,052	$723	$2,595	$1,810
12	Hawaii	$324	$108	$1,488	$834	$3,424	$2,485
13	Idaho	$0	$0	$418	$339	$2,000	$1,458
14	Illinois	$247	$204	$813	$594	$1,740	$1,135
15	Indiana	$191	$175	$690	$650	$1,416	$1,280
16	Iowa	$0	$131	$723	$807	$2,248	$1,938
17	Kansas	$51	$48	$637	$585	$1,798	$1,518
18	Kentucky	$148	$108	$764	$687	$1,678	$1,494
19	Louisiana	$0	$0	$195	$173	$892	$712
20	Maine	$67	$50	$458	$541	$1,587	$1,678
21	Maryland	$443	$304	$1,398	$1,047	$2,778	$2,095
22	Massachusetts	$478	$112	$1,674	$1,016	$4,519	$2,267
23	Michigan	$0	$0	$1,341	$698	$2,896	$1,851
24	Minnesota	$86	$200	$1,151	$1,143	$2,872	$2,689
25	Mississippi	$0	$0	$111	$40	$1,248	$661
26	Missouri	$98	$74	$604	$508	$1,561	$1,323
27	Montana	$1	$0	$410	$531	$1,543	$1,287
28	Nebraska	$15	$107	$342	$487	$1,342	$1,078
29	Nevada	$0	$0	$0	$0	$0	$0
30	New Hampshire	$0	$0	$0	$0	$95	$0
31	New Jersey	$293	$151	$1,043	$551	$2,797	$1,271
32	New Mexico	$0	$0	$152	$164	$943	$859
33	New York	$318	$0	$2,906	$1,134	$7,919	$3,027
34	North Carolina	$220	$177	$1,000	$798	$2,832	$1,989
35	North Dakota	$0	$0	$221	$256	$751	$706
36	Ohio	$74	$14	$854	$488	$2,432	$1,318
37	Oklahoma	$38	$30	$567	$400	$1,873	$1,353
38	Oregon	$0	$0	$404	$0	$1,565	$960
39	Pennsylvania	$259	$171	$678	$480	$1,472	$907
40	Rhode Island	$72	$162	$545	$625	$1,866	$1,671
41	South Carolina	$40	$35	$536	$521	$1,867	$1,511
42	South Dakota	$0	$0	$0	$0	$0	$0
43	Tennesse	$0	$0	$11	$2	$140	$41
44	Texas	$0	$0	$0	$0	$0	$0
45	Utah	$179	$77	$900	$943	$2,065	$2,240
46	Vermont	$136	$0	$771	$301	$2,071	$1,086
47	Virginia	$139	$108	$1,124	$911	$2,879	$2,225
48	Washington	$0	$0	$0	$0	$0	$0
49	West Virginia	$114	$168	$458	$553	$1,736	$1,203
50	Wisconsin	$0	$0	$1,040	$854	$3,125	$2,021
51	Wyoming	$0	$0	$0	$0	$0	$0

Source: authors' calculations with 1985 and 1987 SOI databases and

the 1985 and 1987 NBER simulations of state personal income tax liabilities.

Table 5-2: The Pattern of Effective State Personal Income Tax Rates in %: 1985 &87

ID		First Quartile		Median		Third Quartile	
		85 State	87 State	85 State	87 State	85 State	87 State
	All States	0.0%	0.0%	1.9%	1.3%	3.4%	3.0%
1	Alabama	1.3%	0.3%	2.0%	1.9%	2.5%	2.6%
2	Alaska	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	Arizona	0.0%	0.0%	2.2%	1.7%	3.3%	3.5%
4	Arkansas	0.3%	0.0%	2.5%	1.8%	3.9%	3.7%
5	California	0.0%	0.0%	1.9%	0.7%	4.1%	3.1%
6	Colorado	0.6%	0.5%	2.4%	2.6%	3.4%	3.5%
7	Connecticut	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%
8	Delaware	2.4%	0.3%	4.5%	3.1%	5.9%	4.3%
9	DC	1.9%	0.0%	5.2%	4.1%	7.1%	6.4%
10	Florida	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11	Georgia	1.2%	0.5%	3.1%	2.7%	4.0%	3.8%
12	Hawaii	1.7%	0.0%	4.2%	3.6%	5.7%	5.5%
13	Idaho	0.0%	0.0%	2.2%	1.1%	4.1%	3.9%
14	Illinois	1.8%	1.6%	2.1%	2.1%	2.2%	2.3%
15	Indiana	1.7%	1.6%	2.4%	2.6%	2.6%	2.9%
16	Iowa	0.0%	0.0%	3.0%	3.3%	4.4%	4.5%
17	Kansas	0.5%	0.0%	2.1%	2.2%	3.0%	3.3%
18	Kentucky	1.3%	0.8%	2.9%	3.0%	3.4%	3.8%
19	Louisiana	0.0%	0.0%	0.8%	0.9%	1.5%	1.7%
20	Maine	0.7%	0.0%	2.1%	1.9%	3.7%	4.0%
21	Maryland	2.3%	1.2%	3.3%	3.2%	3.8%	3.8%
22	Massachusetts	2.5%	0.0%	4.1%	3.3%	4.9%	4.1%
23	Michigan	0.0%	0.0%	3.5%	1.9%	4.6%	3.9%
24	Minnesota	0.6%	0.6%	3.2%	3.6%	4.3%	5.4%
25	Mississippi	0.0%	0.0%	0.6%	0.2%	2.3%	1.8%
26	Missouri	0.7%	0.3%	1.9%	1.8%	2.5%	2.7%
27	Montana	0.0%	0.0%	1.8%	2.5%	3.8%	4.1%
28	Nebraska	0.1%	0.5%	1.7%	1.9%	2.8%	2.3%
29	Nevada	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
30	New Hampshire	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
31	New Jersey	1.5%	0.8%	2.0%	1.7%	2.7%	2.1%
32	New Mexico	0.0%	0.0%	0.7%	0.7%	1.8%	1.9%
33	New York	1.7%	0.0%	6.0%	2.9%	9.8%	5.2%
34	North Carolina	2.0%	1.4%	3.6%	3.4%	4.6%	4.6%
35	North Dakota	0.0%	0.0%	0.9%	1.0%	1.5%	1.5%
36	Ohio	0.6%	0.0%	2.6%	1.6%	3.8%	2.8%
37	Oklahoma	0.4%	0.2%	1.8%	1.6%	3.1%	3.2%
38	Oregon	0.0%	0.0%	1.4%	0.0%	3.7%	2.3%
39	Pennsylvania	1.9%	0.3%	2.3%	2.0%	2.4%	2.1%
40	Rhode Island	0.9%	0.8%	2.3%	2.1%	3.1%	3.0%
41	South Carolina	0.3%	0.2%	2.0%	2.3%	3.3%	3.8%
42	South Dakota	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
43	Tennesse	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%
44	Texas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
45	Utah	1.3%	0.3%	3.2%	3.4%	4.2%	5.1%
46	Vermont	1.1%	0.0%	2.6%	1.4%	3.6%	2.7%
47	Virginia	0.9%	0.0%	2.8%	2.6%	3.8%	3.9%
48	Washington	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
49	West Virginia	1.4%	1.7%	2.2%	2.5%	3.4%	3.1%
50	Wisconsin	0.0%	0.0%	3.3%	2.6%	5.1%	4.5%
51	Wyoming	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: authors' calculations with 1985 and 1987 SOI databases and the 1985 and 1987 NBER simulations of state personal income tax liabilities.

Table 5-3: The Pattern of Effective Federal Personal Income Tax Rates in %: 1985 & 87

ID		First Quartile		Median		Third Quartile	
		85 State	87 State	85 State	87 State	85 State	87 State
	All States	5.2%	3.5%	10.8%	8.7%	16.1%	12.8%
1	Alabama	3.9%	0.0%	9.3%	7.3%	14.5%	10.8%
2	Alaska	7.7%	0.0%	14.2%	9.8%	19.0%	15.1%
3	Arizona	4.2%	0.9%	9.8%	7.4%	14.7%	11.0%
4	Arkansas	1.9%	0.7%	8.7%	7.1%	13.6%	10.5%
5	California	4.7%	1.9%	10.4%	8.2%	15.3%	12.5%
6	Colorado	4.0%	1.7%	9.9%	7.9%	14.8%	12.0%
7	Connecticut	8.7%	4.9%	14.0%	10.3%	19.2%	14.7%
8	Delaware	6.6%	3.0%	11.3%	8.9%	16.8%	11.9%
9	DC	6.9%	1.0%	12.6%	8.6%	18.2%	12.8%
10	Florida	4.6%	1.8%	10.2%	7.9%	16.4%	11.5%
11	Georgia	5.2%	2.0%	10.8%	8.3%	15.7%	11.8%
12	Hawaii	5.1%	1.5%	9.6%	7.8%	14.4%	11.2%
13	Idaho	0.2%	0.0%	7.3%	5.8%	11.6%	9.8%
14	Illinois	6.3%	2.4%	11.8%	8.8%	17.5%	12.9%
15	Indiana	4.8%	1.9%	10.4%	8.3%	15.5%	11.6%
16	Iowa	2.5%	2.0%	8.6%	7.6%	13.9%	10.7%
17	Kansas	3.8%	1.4%	10.2%	7.9%	15.6%	11.0%
18	Kentucky	3.9%	0.6%	9.3%	7.2%	14.3%	10.4%
19	Louisiana	2.9%	0.0%	9.9%	6.6%	15.7%	10.4%
20	Maine	4.7%	1.6%	9.1%	7.4%	12.8%	10.6%
21	Maryland	7.0%	4.0%	11.8%	9.0%	16.9%	12.7%
22	Massachusetts	7.4%	4.2%	12.4%	9.5%	17.3%	13.3%
23	Michigan	6.1%	3.1%	11.9%	8.8%	16.7%	12.8%
24	Minnesota	5.5%	2.2%	10.4%	7.9%	14.8%	11.3%
25	Mississippi	0.0%	0.0%	7.7%	5.3%	13.2%	9.5%
26	Missouri	5.0%	1.2%	10.7%	7.7%	15.9%	11.5%
27	Montana	0.0%	0.0%	6.8%	6.3%	12.1%	10.1%
28	Nebraska	1.2%	1.5%	8.1%	7.7%	13.8%	10.3%
29	Nevada	3.9%	0.6%	10.5%	8.3%	15.7%	12.2%
30	New Hampshire	6.8%	4.3%	11.6%	8.6%	16.7%	12.2%
31	New Jersey	8.1%	3.6%	13.5%	9.5%	18.9%	14.4%
32	New Mexico	2.2%	0.0%	8.4%	6.7%	14.4%	10.7%
33	New York	6.8%	2.8%	11.8%	8.7%	16.6%	12.7%
34	North Carolina	4.4%	2.1%	9.8%	7.9%	14.6%	11.0%
35	North Dakota	1.8%	0.0%	8.3%	6.9%	14.1%	10.7%
36	Ohio	6.0%	2.3%	11.0%	8.5%	15.9%	11.7%
37	Oklahoma	3.5%	0.0%	9.6%	6.9%	15.1%	10.5%
38	Oregon	3.0%	0.3%	8.8%	7.1%	13.3%	10.3%
39	Pennsylvania	5.7%	2.3%	10.8%	8.4%	16.1%	11.7%
40	Rhode Island	4.1%	4.5%	10.0%	8.8%	13.8%	12.4%
41	South Carolina	4.2%	1.2%	9.2%	7.5%	13.8%	10.4%
42	South Dakota	0.0%	0.1%	7.3%	7.2%	11.7%	9.8%
43	Tennesse	3.8%	1.9%	10.1%	8.2%	15.7%	11.5%
44	Texas	4.1%	1.2%	11.1%	8.0%	17.1%	12.1%
45	Utah	3.8%	0.6%	7.9%	6.5%	12.5%	10.3%
46	Vermont	5.3%	3.5%	10.0%	8.1%	14.3%	11.2%
47	Virginia	6.6%	3.2%	11.7%	8.7%	16.6%	12.9%
48	Washington	5.2%	4.5%	10.6%	8.8%	15.9%	12.7%
49	West Virginia	5.1%	1.9%	10.4%	8.0%	15.4%	11.0%
50	Wisconsin	4.7%	1.8%	9.9%	7.8%	14.9%	10.9%
51	Wyoming	4.8%	0.0%	11.8%	7.3%	16.8%	10.5%

Source: authors' calculations with 1985 and 1987 SOI databases and

the 1985 and 1987 NBER simulations of state personal income tax liabilities.

Table 5-4: The Pattern of Combined Effective State & Federal Personal Tax Rates in % : 1985 &87

		First Quartile		Median		Third Quartile	
	ID	85 State	87 State	85 State	87 State	85 State	87 State
	All States	6.2%	4.1%	13.1%	10.4%	19.4%	15.6%
1	Alabama	5.0%	0.4%	11.3%	9.2%	17.1%	13.4%
2	Alaska	7.7%	0.0%	14.2%	9.8%	19.0%	15.1%
3	Arizona	4.8%	1.1%	12.1%	9.1%	17.9%	14.4%
4	Arkansas	2.4%	1.0%	11.1%	9.0%	17.6%	13.8%
5	California	5.1%	2.1%	12.3%	9.0%	19.3%	15.5%
6	Colorado	5.3%	2.7%	12.3%	10.6%	18.0%	15.4%
7	Connecticut	8.9%	5.0%	14.4%	10.4%	20.0%	15.1%
8	Delaware	8.4%	3.9%	16.0%	12.2%	23.1%	16.0%
9	DC	8.7%	1.2%	18.3%	12.8%	25.2%	19.3%
10	Florida	4.6%	1.8%	10.2%	7.9%	16.4%	11.5%
11	Georgia	6.5%	2.8%	14.0%	10.9%	19.5%	15.5%
12	Hawaii	7.6%	1.8%	13.5%	11.5%	19.4%	16.8%
13	Idaho	0.5%	0.0%	9.6%	7.1%	15.9%	13.9%
14	Illinois	8.1%	3.9%	13.9%	10.9%	19.6%	15.1%
15	Indiana	6.7%	3.4%	12.8%	10.9%	18.1%	14.5%
16	Iowa	3.2%	3.2%	11.6%	10.8%	18.0%	15.2%
17	Kansas	4.5%	1.8%	12.3%	10.1%	18.4%	14.3%
18	Kentucky	5.6%	1.8%	12.3%	10.2%	17.7%	14.2%
19	Louisiana	3.0%	0.0%	10.6%	7.5%	17.2%	11.9%
20	Maine	5.4%	2.1%	11.1%	9.8%	16.5%	14.6%
21	Maryland	9.4%	5.3%	15.0%	12.2%	20.5%	16.4%
22	Massachusetts	10.5%	5.2%	16.7%	12.6%	22.2%	17.4%
23	Michigan	7.1%	3.3%	15.3%	10.9%	21.0%	16.3%
24	Minnesota	6.2%	3.2%	13.5%	11.5%	19.0%	16.6%
25	Mississippi	0.0%	0.0%	8.2%	5.6%	15.4%	11.2%
26	Missouri	5.8%	1.8%	12.7%	9.6%	18.4%	14.3%
27	Montana	0.3%	0.0%	8.6%	8.9%	16.3%	14.1%
28	Nebraska	1.8%	2.2%	9.9%	9.5%	16.5%	12.6%
29	Nevada	3.9%	0.6%	10.5%	8.3%	15.7%	12.2%
30	New Hampshire	7.6%	4.7%	11.7%	8.8%	16.9%	12.5%
31	New Jersey	10.0%	4.6%	15.6%	11.2%	21.3%	16.4%
32	New Mexico	2.3%	0.0%	9.1%	7.4%	16.1%	12.7%
33	New York	9.7%	3.1%	18.5%	11.5%	25.8%	17.8%
34	North Carolina	6.7%	3.5%	13.4%	11.2%	19.3%	15.6%
35	North Dakota	1.8%	0.0%	9.2%	7.4%	15.5%	12.0%
36	Ohio	6.8%	2.5%	13.7%	10.2%	19.5%	14.4%
37	Oklahoma	4.1%	0.3%	11.4%	8.6%	18.2%	13.7%
38	Oregon	3.3%	0.3%	10.6%	7.6%	16.5%	12.4%
39	Pennsylvania	7.7%	3.2%	13.1%	10.4%	18.4%	13.7%
40	Rhode Island	4.9%	5.6%	12.3%	11.1%	16.8%	15.3%
41	South Carolina	4.8%	1.5%	11.1%	9.8%	16.9%	14.1%
42	South Dakota	0.0%	0.1%	7.3%	7.2%	11.7%	9.8%
43	Tennesse	4.2%	2.4%	10.6%	8.4%	16.0%	11.8%
44	Texas	4.1%	1.2%	11.1%	8.0%	17.1%	12.1%
45	Utah	5.4%	1.7%	11.5%	9.7%	16.6%	15.4%
46	Vermont	7.1%	4.0%	12.5%	9.7%	17.5%	13.5%
47	Virginia	7.5%	3.5%	14.5%	11.3%	20.3%	16.8%
48	Washington	5.2%	4.5%	10.6%	8.8%	15.9%	12.7%
49	West Virginia	6.6%	3.7%	12.7%	10.5%	18.3%	14.1%
50	Wisconsin	5.5%	2.1%	12.9%	9.9%	19.9%	15.2%
51	Wyoming	4.8%	0.0%	11.8%	7.3%	16.8%	10.5%

Source: authors' calculations with 1985 and 1987 SOI databases and

the 1985 and 1987 NBER simulations of state personal income tax liabilities.

Utah, which conformed their exemptions and standard deduction to the federal rules, experienced substantial *increases* in progressivity. Of particular interest is the observation that geographic neighbors, such as Illinois, Indiana, Ohio, or Pennsylvania, New York, and New Jersey display vastly different vertical equity characteristics in their individual income taxes. Between 1985 and 1987, only 13 states experienced a decline in the horizontal equity of their personal income taxes. If we compare the progressivity score for taxpayers across all states, we find it fell from 67.6% to 63.8%.

It is also quite evident from Table 5-5 that the states vary widely in the extent of the horizontal equity of their personal income taxes. In New Hampshire, 77% of the paired comparisons display horizontal equity, while only 14.4% in Maryland display horizontal equity in 1985. Of course New Hampshire is unusual in that it taxes only a limited portion of income.

5.3. The Progressivity of the Federal Individual Income Tax by State: 1985 & 87

While 37 states experienced a decline in progressivity of their state personal income taxes between 1985 and 1987, we find that federal taxpayers in 32 states experienced a decline in progressivity. Moreover, it is evident from inspection of the 32 states in question that they involve a majority of the US federal taxpayers. Horizontal equity declined in all states between 1985 and 1987.

5.4. The Progressivity of the State and Federal Individual Income Taxes by State: 1985 & 87

The combined effect of the state and federal tax systems, 1985 compared to 1987, is displayed in Table 5-7. Overall, the *system* of personal taxation became less progressive in 24 states, and became less equitable horizontally in 39 states. It is evident from the size of the states which experienced *declines* in the overall progressivity scores between 1985 and 1987 that for the majority of taxpayers when compared to each other in each state, the *system* of state and federal individual income taxes became less progressive, and less equitable horizontally.

5.5. Do State Individual Income Taxes Make the System More Progressive?

We conclude our review of state and federal personal income taxes by examining whether the addition of the state personal income taxes, which vary so widely in terms of their own progressivity, has a discernable effect in each state on the overall progressivity of the system. If we take as our base case the federal individual income tax, and compare it to the combined tax system of state and federal personal income taxes using the dynamic progressivity measures discussed in Section 3, we find that for the vast majority of states, the imposition of the state personal income tax either increases the extent to which the overall personal income tax system is progressive in each state, or the extent to which it is proportional. (See table 5-8 below).

Table 5-5: Progressivity and Horizontal Equity Index Values of State Personal Income Taxes: 1985 & 1987

	STATE	85 Prog	87 Prog	% Change	85 Horiz Eq	87 Horiz Eq	% Change
	All States	0.6757	0.6376	(5.6%)	0.2220	0.2560	15%
1	Alabama	0.8001	0.8126	1.6%	0.2481	0.2918	18%
2	Alaska	0.0000	0.0000	.	1.0000	1.0000	0.0%
3	Arizona	0.8190	0.7336	(10%)	0.3450	0.3905	13%
4	Arkansas	0.8752	0.8279	(5.4%)	0.2811	0.3080	9.6%
5	California	0.8175	0.7391	(9.6%)	0.4109	0.4591	12%
6	Colorado	0.6439	0.6255	(2.9%)	0.1997	0.2247	13%
7	Connecticut	0.3030	0.2023	(33%)	0.8874	0.8555	(3.6%)
8	Delaware	0.8796	0.7838	(11%)	0.2437	0.2790	14%
9	DC	0.8614	0.7695	(11%)	0.3888	0.3930	1.1%
10	Florida	0.0000	0.0000	.	1.0000	1.0000	0.0%
11	Georgia	0.8430	0.8302	(1.5%)	0.2247	0.2301	2.4%
12	Hawaii	0.7020	0.5136	(27%)	0.2231	0.2540	14%
13	Idaho	0.8246	0.7822	(5.1%)	0.3389	0.3586	5.8%
14	Illinois	0.5872	0.5173	(12%)	0.2733	0.2826	3.4%
15	Indiana	0.7656	0.7281	(4.9%)	0.2792	0.3220	15%
16	Iowa	0.8678	0.7400	(15%)	0.3216	0.2409	(25%)
17	Kansas	0.7725	0.7435	(3.8%)	0.2312	0.2996	30%
18	Kentucky	0.7748	0.7674	(1.0%)	0.2357	0.2399	1.8%
19	Louisiana	0.7723	0.7042	(8.8%)	0.4220	0.3916	(7.2%)
20	Maine	0.8674	0.6559	(24%)	0.3025	0.1852	(39%)
21	Maryland	0.6812	0.6856	0.6%	0.1437	0.1948	36%
22	Massachusetts	0.8573	0.7830	(8.7%)	0.2531	0.3292	30%
23	Michigan	0.8343	0.8003	(4.1%)	0.3738	0.4399	18%
24	Minnesota	0.8052	0.7687	(4.5%)	0.2539	0.2026	(20%)
25	Mississippi	0.8247	0.8086	(2.0%)	0.5909	0.5362	(9.3%)
26	Missouri	0.8135	0.7895	(3.0%)	0.2642	0.2808	6.3%
27	Montana	0.7971	0.8150	2.2%	0.3091	0.2948	(4.6%)
28	Nebraska	0.7849	0.7780	(0.9%)	0.3199	0.2884	(9.8%)
29	Nevada	0.0000	0.0000	.	1.0000	1.0000	0.0%
30	New Hampshire	0.2330	0.1316	(44%)	0.7707	0.7864	2.0%
31	New Jersey	0.8297	0.7372	(11%)	0.3030	0.3325	9.7%
32	New Mexico	0.7935	0.6972	(12%)	0.4135	0.4451	7.6%
33	New York	0.8168	0.7883	(3.5%)	0.2205	0.3287	49%
34	North Carolina	0.8467	0.7895	(6.8%)	0.1753	0.1941	11%
35	North Dakota	0.6332	0.3783	(40%)	0.4779	0.4616	(3.4%)
36	Ohio	0.8916	0.8080	(9.4%)	0.3260	0.3556	9.1%
37	Oklahoma	0.7652	0.7289	(4.7%)	0.2246	0.2287	1.8%
38	Oregon	0.7071	0.6673	(5.6%)	0.4095	0.5266	29%
39	Pennsylvania	0.4824	0.4798	(0.5%)	0.4674	0.4902	4.9%
40	Rhode Island	0.8471	0.8279	(2.3%)	0.3133	0.2654	(15%)
41	South Carolina	0.8236	0.8680	5.4%	0.3054	0.2639	(14%)
42	South Dakota	0.0000	0.0000	.	1.0000	1.0000	0.0%
43	Tennesse	0.2286	0.1523	(33%)	0.6601	0.6822	3.3%
44	Texas	0.0000	0.0000	.	1.0000	1.0000	0.0%
45	Utah	0.6895	0.7476	8.4%	0.1786	0.2168	21%
46	Vermont	0.8264	0.8522	3.1%	0.4060	0.4332	6.7%
47	Virginia	0.8482	0.7815	(7.9%)	0.3045	0.2565	(16%)
48	Washington	0.0000	0.0000	.	1.0000	1.0000	0.0%
49	West Virginia	0.8018	0.8203	2.3%	0.2377	0.1984	(17%)
50	Wisconsin	0.8830	0.7502	(15%)	0.3824	0.4571	20%
51	Wyoming	0.0000	0.0000	.	1.0000	1.0000	0.0%

Source: authors' calculations with 1985 and 1987 SOI databases and the 1985 and 1987 NBER simulations of state personal income tax liabilities.

Table 5-6: Progressivity
and Horizontal Equity of Federal Individual Income Tax: 1985 & 87

	STATE	85 Prog	87 Prog	% Change	85 Horiz Eq	87 Horiz Eq	% Change
	All States	0.9467	0.9364	(1.1%)	0.0362	0.0232	(36%)
1	Alabama	0.9771	0.9588	(1.9%)	0.0408	0.0232	(43.1%)
2	Alaska	0.9668	0.4163	(56.9%)	0.0987	0.1639	66.1%
3	Arizona	0.9437	0.9315	(1.3%)	0.0527	0.0281	(46.7%)
4	Arkansas	0.9692	0.7814	(19.4%)	0.0514	0.0263	(48.8%)
5	California	0.9371	0.9314	(0.6%)	0.0314	0.0218	(30.6%)
6	Colorado	0.8458	0.9066	7.2%	0.0973	0.0326	(66.5%)
7	Connecticut	0.9170	0.8684	(5.3%)	0.0607	0.0387	(36.2%)
8	Delaware	0.9618	0.9705	0.9%	0.1112	0.0497	(55.3%)
9	DC	0.9650	0.9600	(0.5%)	0.0725	0.0727	0.3%
10	Florida	0.9494	0.9567	0.8%	0.0361	0.0234	(35.2%)
11	Georgia	0.9714	0.9667	(0.5%)	0.0306	0.0195	(36.3%)
12	Hawaii	0.9220	0.7281	(21.0%)	0.1145	0.0883	(22.9%)
13	Idaho	0.9256	0.9518	2.8%	0.1035	0.0635	(38.6%)
14	Illinois	0.9632	0.9341	(3.0%)	0.0427	0.0265	(37.9%)
15	Indiana	0.9566	0.9389	(1.9%)	0.0592	0.0306	(48.3%)
16	Iowa	0.9411	0.8989	(4.5%)	0.0688	0.0526	(23.5%)
17	Kansas	0.9546	0.9073	(5.0%)	0.0522	0.0391	(25.1%)
18	Kentucky	0.9601	0.9586	(0.2%)	0.0500	0.0278	(44.4%)
19	Louisiana	0.9628	0.9222	(4.2%)	0.0343	0.0206	(39.9%)
20	Maine	0.8978	0.9450	5.3%	0.1924	0.0822	(57.3%)
21	Maryland	0.9465	0.9434	(0.3%)	0.0441	0.0303	(31.3%)
22	Massachusetts	0.9340	0.9261	(0.8%)	0.0622	0.0433	(30.4%)
23	Michigan	0.9633	0.9495	(1.4%)	0.0515	0.0420	(18.4%)
24	Minnesota	0.9268	0.8990	(3.0%)	0.0651	0.0485	(25.5%)
25	Mississippi	0.9798	0.9568	(2.3%)	0.0358	0.0249	(30.4%)
26	Missouri	0.9618	0.9681	0.7%	0.0551	0.0264	(52.1%)
27	Montana	0.9222	0.9079	(1.6%)	0.1737	0.0698	(59.8%)
28	Nebraska	0.9217	0.9282	0.7%	0.0801	0.0421	(47.4%)
29	Nevada	0.9032	0.9149	1.3%	0.1540	0.0472	(69.4%)
30	New Hampshire	0.9467	0.9566	1.0%	0.1432	0.0547	(61.8%)
31	New Jersey	0.9461	0.9429	(0.3%)	0.0419	0.0215	(48.7%)
32	New Mexico	0.9576	0.9606	0.3%	0.0518	0.0339	(34.6%)
33	New York	0.9152	0.9376	2.4%	0.0315	0.0218	(30.8%)
34	North Carolina	0.9525	0.9570	0.5%	0.0566	0.0232	(59.0%)
35	North Dakota	0.9012	0.6544	(27.4%)	0.1585	0.1168	(26.3%)
36	Ohio	0.9545	0.9350	(2.0%)	0.0489	0.0369	(24.5%)
37	Oklahoma	0.9331	0.8962	(4.0%)	0.0450	0.0416	(7.6%)
38	Oregon	0.9309	0.9372	0.7%	0.0761	0.0409	(46.3%)
39	Pennsylvania	0.9437	0.9318	(1.3%)	0.0639	0.0387	(39.4%)
40	Rhode Island	0.9190	0.9299	1.2%	0.1584	0.0925	(41.6%)
41	South Carolina	0.9329	0.9560	2.5%	0.0697	0.0263	(62.3%)
42	South Dakota	0.9405	0.9286	(1.3%)	0.1182	0.0716	(39.4%)
43	Tennesse	0.9750	0.9647	(1.1%)	0.0411	0.0201	(51.1%)
44	Texas	0.9437	0.9357	(0.8%)	0.0327	0.0208	(36.4%)
45	Utah	0.9453	0.9042	(4.3%)	0.0802	0.0624	(22.2%)
46	Vermont	0.9281	0.9648	4.0%	0.1314	0.0748	(43.1%)
47	Virginia	0.9557	0.9410	(1.5%)	0.0536	0.0326	(39.2%)
48	Washington	0.9339	0.9563	2.4%	0.0675	0.0292	(56.7%)
49	West Virginia	0.9646	0.9668	0.2%	0.0718	0.0392	(45.4%)
50	Wisconsin	0.9401	0.9198	(2.2%)	0.0741	0.0357	(51.8%)
51	Wyoming	0.9181	0.9339	1.7%	0.2059	0.0913	(55.7%)

Source: authors' calculations with 1985 and 1987 SOI databases and

the 1985 and 1987 NBER simulations of state personal income tax liabilities.

Table 5-7: Progressivity and Horizontal Equity of State and Federal Individual Income Taxes: 1985 & 87

OBS	STATE	85 Prog	87 Prog	% Change	85 Horiz Eq	87 Horiz Eq	% Change
	All US	0.9496	0.9386	(1.2%)	0.0283	0.0179	(37%)
1	Alabama	0.9782	0.9630	(1.6%)	0.0310	0.0218	(30%)
2	Alaska	0.9668	0.4163	(57%)	0.0987	0.1639	66%
3	Arizona	0.9518	0.9410	(1.1%)	0.0470	0.0266	(43%)
4	Arkansas	0.9739	0.8074	(17%)	0.0470	0.0255	(46%)
5	California	0.9458	0.9362	(1.0%)	0.0300	0.0205	(32%)
6	Colorado	0.8539	0.9104	6.6%	0.0803	0.0296	(63%)
7	Connecticut	0.9219	0.8686	(5.8%)	0.0602	0.0374	(38%)
8	Delaware	0.9647	0.9742	1.0%	0.1035	0.0465	(55%)
9	DC	0.9728	0.9669	(0.6%)	0.0698	0.0675	(3.3%)
10	Florida	0.9494	0.9567	0.8%	0.0361	0.0234	(35%)
11	Georgia	0.9741	0.9702	(0.4%)	0.0275	0.0179	(35%)
12	Hawaii	0.9208	0.7593	(18%)	0.1091	0.0786	(28%)
13	Idaho	0.9360	0.9568	2.2%	0.0956	0.0577	(40%)
14	Illinois	0.9594	0.9311	(2.9%)	0.0248	0.0164	(34%)
15	Indiana	0.9587	0.9302	(3.0%)	0.0488	0.0244	(50%)
16	Iowa	0.9505	0.9079	(4.5%)	0.0660	0.0482	(27%)
17	Kansas	0.9562	0.9182	(4.0%)	0.0459	0.0358	(22%)
18	Kentucky	0.9638	0.9641	0.0%	0.0448	0.0241	(46%)
19	Louisiana	0.9642	0.9267	(3.9%)	0.0328	0.0194	(41%)
20	Maine	0.9088	0.8901	(2.1%)	0.1802	0.0636	(65%)
21	Maryland	0.9437	0.9443	0.1%	0.0250	0.0219	(12%)
22	Massachusetts	0.9436	0.9356	(0.8%)	0.0593	0.0397	(33%)
23	Michigan	0.9701	0.9586	(1.2%)	0.0494	0.0396	(20%)
24	Minnesota	0.9347	0.9144	(2.2%)	0.0608	0.0422	(31%)
25	Mississippi	0.9819	0.9612	(2.1%)	0.0354	0.0242	(32%)
26	Missouri	0.9637	0.9655	0.2%	0.0525	0.0250	(52%)
27	Montana	0.9272	0.9248	(0.3%)	0.1469	0.0607	(59%)
28	Nebraska	0.9303	0.9350	0.5%	0.0752	0.0384	(49%)
29	Nevada	0.9032	0.9149	1.3%	0.1540	0.0472	(69%)
30	New Hampshire	0.9514	0.9565	0.5%	0.1401	0.0526	(62%)
31	New Jersey	0.9471	0.9363	(1.1%)	0.0376	0.0185	(51%)
32	New Mexico	0.9604	0.9112	(5.1%)	0.0512	0.0334	(35%)
33	New York	0.9384	0.9495	1.2%	0.0292	0.0190	(35%)
34	North Carolina	0.9561	0.9627	0.7%	0.0471	0.0203	(57%)
35	North Dakota	0.9082	0.6730	(26%)	0.1609	0.1129	(30%)
36	Ohio	0.9645	0.9433	(2.2%)	0.0468	0.0352	(25%)
37	Oklahoma	0.9342	0.9079	(2.8%)	0.0411	0.0346	(16%)
38	Oregon	0.9366	0.9446	0.9%	0.0732	0.0383	(48%)
39	Pennsylvania	0.9392	0.9302	(1.0%)	0.0621	0.0371	(40%)
40	Rhode Island	0.9247	0.9374	1.4%	0.1506	0.0892	(41%)
41	South Carolina	0.9429	0.9630	2.1%	0.0661	0.0243	(63%)
42	South Dakota	0.9405	0.9286	(1.3%)	0.1182	0.0716	(39%)
43	Tennesse	0.9458	0.9314	(1.5%)	0.0361	0.0178	(51%)
44	Texas	0.9437	0.9357	(0.8%)	0.0327	0.0208	(36%)
45	Utah	0.9311	0.9025	(3.1%)	0.0609	0.0560	(8.0%)
46	Vermont	0.9456	0.9708	2.7%	0.1239	0.0718	(42%)
47	Virginia	0.9610	0.9470	(1.5%)	0.0512	0.0297	(42%)
48	Washington	0.9339	0.9563	2.4%	0.0675	0.0292	(57%)
49	West Virginia	0.9659	0.9708	0.5%	0.0562	0.0241	(57%)
50	Wisconsin	0.9571	0.9266	(3.2%)	0.0711	0.0337	(53%)
51	Wyoming	0.9181	0.9339	1.7%	0.2059	0.0913	(56%)

Source: authors' calculations with 1985 and 1987 SOI databases and the 1985 and 1987 NBER simulations of state personal income tax liabilities.

Another way to examine the role of state individual income taxes in our federal system of individual income taxes is to compare the after-tax Gini coefficient of income inequality that reflects just the impact of the federal individual income tax to the Gini obtained when one accounts for both the state and federal individual income taxes. Table 5-9 displays this for both 1985 and 1987, and indicates that in both 1985 and 1987 the effect of the state individual income taxes in virtually every state was to make the after-tax income distribution more equal as evidenced by the smaller Gini coefficients.

5.6. Results for the Gini Coefficient and Coefficient of Variation in Effective Tax Rate Results

Another method for illustrating this point is to compute the change in a measure of income inequality, say the Gini coefficient of after-tax income inequality, across time. Table 5-10 displays this and indicates that 41 of 51 states displayed greater, after-tax income inequality in 1987 as compared to 1985. Moreoever, those states whose combined Gini fell, indicating a deline in after-tax income inequality, were typically smaller states. Overall the Gini grew by 3.2% between 1985 and 1987. With regard to horizontal inequity as captured by the coefficient of variation in effective tax rates, we find that it rose in every state, and by 15% overall between 1985 and 1987.

6. Conclusions

This study of the effects of TRA 1986 on state and federal tax interactions reached several important empirical conclusions. First, there are very sizeable differences among the states in the progressivity of their personal income taxes. Using a specific index number methodology, we find differences of at least two to one in the extent to which major income tax states tax their residents progressively. Second, we find that state personal income taxes generally became less progressive and less horizontally equitable, and that the federal personal income taxes displayed the same results at the state level when we compare effective tax rates in 1987 at the state level to those in 1985. The net impact varied by state; however, if we weight the states by their relative populations or numbers of taxpayers, then it is clear from our analysis that overall, the personal income tax system, when viewed at the state level, became less progressive and less horizontally equitable in 1987 viz a viz 1985.

To be sure, 1987 was a transition year as the federal and state taxable income base were broadened and the federal marginal tax rates lowered, and which took full effect at the federal level in taxable year 1989. Moroever, we now know that second behavioral reaction to the elimination of the capital gains exclusion colored the 1987 data, with an abnormally low amount of capital gains income being reported in 1987 as contrasted with the abnormally high level of capital gains being reported in 1986 in contemplation of the elimination of the exclusion (the first behavioral reaction).

Finally, a number of states, faced with revenue shortfalls in the last several years, partly as a result of overly

Table 5-8: Impact of State Individual Income Taxes on Federal System: 1985 & 87

		1985			1987		
	STATE	Dynamic Progr	Dynamic Regr	Dynamic Proport	Dynamic Progr	Dynamic Regr	Dynamic Proport
	All States	0.5848	0.2198	0.1954	0.5777	0.1984	0.2239
1	Alabama	0.7197	0.1850	0.0952	0.7546	0.1346	0.1108
2	Alaska	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000
3	Arizona	0.6839	0.1302	0.1859	0.6948	0.0969	0.2084
4	Arkansas	0.7488	0.1468	0.1044	0.7404	0.1105	0.1491
5	California	0.6237	0.0979	0.2784	0.5936	0.0862	0.3202
6	Colorado	0.7080	0.2171	0.0749	0.6703	0.2276	0.1021
7	Connecticut	0.1047	0.0192	0.8761	0.0982	0.0463	0.8555
8	Delaware	0.7676	0.1935	0.0390	0.7629	0.1512	0.0858
9	DC	0.7506	0.1231	0.1263	0.7303	0.1243	0.1454
10	Florida	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000
11	Georgia	0.7790	0.1492	0.0718	0.7653	0.1460	0.0887
12	Hawaii	0.6470	0.2879	0.0651	0.6852	0.2149	0.0999
13	Idaho	0.7012	0.1877	0.1110	0.6399	0.1435	0.2166
14	Illinois	0.5451	0.2661	0.1887	0.5586	0.2506	0.1908
15	Indiana	0.6906	0.1736	0.1359	0.7428	0.1285	0.1287
16	Iowa	0.7393	0.1283	0.1324	0.7201	0.1799	0.1000
17	Kansas	0.6749	0.2342	0.0910	0.7201	0.1543	0.1256
18	Kentucky	0.7316	0.1830	0.0854	0.7354	0.1739	0.0907
19	Louisiana	0.6078	0.1290	0.2632	0.7001	0.1100	0.1898
20	Maine	0.7693	0.1634	0.0673	0.7045	0.1960	0.0995
21	Maryland	0.6366	0.2916	0.0718	0.6568	0.2555	0.0877
22	Massachusetts	0.7754	0.1455	0.0791	0.7250	0.1296	0.1454
23	Michigan	0.6693	0.1090	0.2218	0.6642	0.0857	0.2502
24	Minnesota	0.6730	0.1856	0.1415	0.7491	0.1760	0.0749
25	Mississippi	0.5546	0.0491	0.3963	0.5989	0.0504	0.3506
26	Missouri	0.7216	0.1701	0.1082	0.7548	0.1397	0.1055
27	Montana	0.7090	0.2151	0.0760	0.7535	0.1460	0.1004
28	Nebraska	0.7226	0.1538	0.1236	0.7443	0.1533	0.1024
29	Nevada	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000
30	New Hampshire	0.1428	0.1113	0.7459	0.1066	0.0960	0.7974
31	New Jersey	0.7424	0.1378	0.1198	0.7256	0.1588	0.1156
32	New Mexico	0.6791	0.1159	0.2050	0.6384	0.0873	0.2743
33	New York	0.7838	0.1286	0.0877	0.7110	0.1100	0.1790
34	North Carolina	0.7644	0.1843	0.0513	0.7739	0.1715	0.0546
35	North Dakota	0.6236	0.1160	0.2604	0.6966	0.1101	0.1933
36	Ohio	0.7833	0.0845	0.1322	0.7749	0.0827	0.1425
37	Oklahoma	0.7352	0.1701	0.0947	0.7481	0.1601	0.0918
38	Oregon	0.5191	0.1655	0.3154	0.4591	0.1102	0.4307
39	Pennsylvania	0.4355	0.2108	0.3537	0.4649	0.1941	0.3410
40	Rhode Island	0.7260	0.1840	0.0900	0.7299	0.1777	0.0925
41	South Carolina	0.7483	0.1282	0.1235	0.7661	0.1297	0.1042
42	South Dakota	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000
43	Tennesse	0.1912	0.1314	0.6774	0.1436	0.1464	0.7100
44	Texas	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000
45	Utah	0.6442	0.2934	0.0624	0.7290	0.1818	0.0893
46	Vermont	0.7425	0.1537	0.1038	0.6770	0.0851	0.2379
47	Virginia	0.7210	0.1391	0.1399	0.7155	0.1597	0.1247
48	Washington	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000
49	West Virginia	0.7111	0.2190	0.0699	0.7517	0.1780	0.0703
50	Wisconsin	0.6964	0.0973	0.2063	0.6739	0.0786	0.2475
51	Wyoming	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000

Note: base case is federal tax, proposal is federal + state personal taxes Source: authors' calculations with 1985 and 1987 SOI databases and the 1985 and 1987 NBER simulations of state personal income tax liabilities.

Table 5-9: Impact of State Individual Income Taxes on Federal System:
After-Tax Gini Coefficients for 1985 & 87

	After-Tax Gini: 1985			After-Tax Gini: 1987		
Tax:	Fed	Fed+State	%Chg	Fed	Fed+State	%Chg
Alabama	0.450	0.448	(0.5%)	0.456	0.453	(0.6%)
Alaska	0.455	0.455	0.0%	0.640	0.640	0.0%
Arizona	0.459	0.454	(0.9%)	0.474	0.469	(1.0%)
Arkansas	0.435	0.429	(1.4%)	0.507	0.502	(1.0%)
California	0.464	0.458	(1.4%)	0.487	0.481	(1.2%)
Colorado	0.497	0.495	(0.3%)	0.486	0.486	(0.2%)
Connecticut	0.469	0.466	(0.5%)	0.485	0.484	(0.2%)
Delaware	0.456	0.449	(1.6%)	0.446	0.441	(1.1%)
DC	0.448	0.437	(2.3%)	0.440	0.432	(1.8%)
Florida	0.462	0.462	0.0%	0.475	0.475	0.0%
Georgia	0.460	0.456	(0.9%)	0.462	0.458	(1.0%)
Hawaii	0.440	0.437	(0.6%)	0.539	0.539	(0.1%)
Idaho	0.479	0.474	(1.0%)	0.492	0.487	(1.0%)
Illinois	0.458	0.457	(0.2%)	0.462	0.462	(0.0%)
Indiana	0.431	0.430	(0.3%)	0.455	0.453	(0.3%)
Iowa	0.468	0.463	(1.1%)	0.468	0.465	(0.7%)
Kansas	0.463	0.461	(0.5%)	0.476	0.472	(0.7%)
Kentucky	0.443	0.440	(0.6%)	0.451	0.447	(0.7%)
Louisiana	0.485	0.483	(0.4%)	0.493	0.491	(0.5%)
Maine	0.427	0.422	(1.2%)	0.429	0.475	11%
Maryland	0.457	0.457	(0.1%)	0.450	0.449	(0.3%)
Massachusetts	0.443	0.437	(1.2%)	0.453	0.449	(0.9%)
Michigan	0.439	0.433	(1.4%)	0.456	0.450	(1.2%)
Minnesota	0.439	0.434	(1.0%)	0.459	0.454	(1.0%)
Mississippi	0.477	0.473	(1.0%)	0.490	0.485	(0.9%)
Missouri	0.452	0.449	(0.6%)	0.457	0.455	(0.6%)
Montana	0.491	0.488	(0.5%)	0.449	0.444	(1.0%)
Nebraska	0.467	0.463	(0.7%)	0.458	0.456	(0.5%)
Nevada	0.463	0.463	0.0%	0.512	0.512	0.0%
New Hampshire	0.434	0.433	(0.1%)	0.448	0.448	0.0%
New Jersey	0.445	0.443	(0.6%)	0.466	0.465	(0.3%)
New Mexico	0.479	0.476	(0.7%)	0.485	0.481	(0.9%)
New York	0.454	0.441	(2.9%)	0.464	0.457	(1.5%)
North Carolina	0.451	0.446	(1.1%)	0.455	0.451	(0.9%)
North Dakota	0.475	0.473	(0.5%)	0.587	0.586	(0.2%)
Ohio	0.435	0.428	(1.4%)	0.453	0.448	(1.1%)
Oklahoma	0.476	0.472	(0.8%)	0.496	0.493	(0.7%)
Oregon	0.469	0.465	(0.8%)	0.458	0.453	(1.0%)
Pennsylvania	0.432	0.431	(0.2%)	0.454	0.453	(0.1%)
Rhode Island	0.435	0.431	(0.9%)	0.427	0.422	(1.0%)
South Carolina	0.440	0.435	(1.1%)	0.470	0.465	(1.1%)
South Dakota	0.455	0.455	0.0%	0.467	0.467	0.0%
Tennesse	0.465	0.465	0.0%	0.467	0.467	0.0%
Texas	0.479	0.479	0.0%	0.491	0.491	0.0%
Utah	0.452	0.451	(0.4%)	0.473	0.468	(1.0%)
Vermont	0.523	0.519	(0.6%)	0.431	0.426	(1.0%)
Virginia	0.449	0.444	(1.1%)	0.453	0.449	(0.9%)
Washington	0.435	0.435	0.0%	0.441	0.441	0.0%
West Virginia	0.431	0.427	(0.9%)	0.422	0.418	(1.1%)
Wisconsin	0.460	0.452	(1.7%)	0.475	0.470	(1.0%)
Wyoming	0.479	0.479	0.0%	0.490	0.490	0.0%

Note: the base case is federal tax, proposal is federal + state personal taxes

Source: authors' calculations with 1985 and 1987 SOI databases and

the 1985 and 1987 NBER simulations of state personal income tax liabilities.

Table 5-10: Impact of State and Federal Individual Income Taxes on After-tax Gini Coefficent and Coefficient of Variation in Effective Tax Rates: 1985 & 87

	STATE	Gini			Coef of Variation in Effective Tax Rate		
		1985	1987	CHG	1985	1987	CHG
	All States	0.453	0.468	3.2%	0.433	0.499	15%
1	Alabama	0.448	0.453	1.1%	0.413	0.481	16%
2	Alaska	0.455	0.640	40%	0.291	0.476	64%
3	Arizona	0.454	0.469	3.3%	0.396	0.464	17%
4	Arkansas	0.429	0.502	17%	0.412	0.473	15%
5	California	0.458	0.481	5.2%	0.490	0.524	7.0%
6	Colorado	0.495	0.486	(2.0%)	0.332	0.393	18%
7	Connecticut	0.466	0.484	3.7%	0.337	0.410	22%
8	Delaware	0.449	0.441	(1.6%)	0.346	0.371	7.3%
9	DC	0.437	0.432	(1.3%)	0.362	0.386	6.7%
10	Florida	0.462	0.475	2.8%	0.437	0.503	15%
11	Georgia	0.456	0.458	0.4%	0.456	0.519	14%
12	Hawaii	0.437	0.539	23%	0.382	0.417	9.1%
13	Idaho	0.474	0.487	2.6%	0.373	0.426	14%
14	Illinois	0.457	0.462	1.1%	0.401	0.458	14%
15	Indiana	0.430	0.453	5.4%	0.334	0.411	23%
16	Iowa	0.463	0.465	0.4%	0.365	0.382	4.5%
17	Kansas	0.461	0.472	2.5%	0.391	0.461	18%
18	Kentucky	0.440	0.447	1.6%	0.376	0.427	14%
19	Louisiana	0.483	0.491	1.7%	0.439	0.554	26%
20	Maine	0.422	0.475	13%	0.238	0.540	126%
21	Maryland	0.457	0.449	(1.8%)	0.388	0.448	16%
22	Massachusetts	0.437	0.449	2.6%	0.366	0.369	0.8%
23	Michigan	0.433	0.450	4.1%	0.356	0.375	5.5%
24	Minnesota	0.434	0.454	4.6%	0.359	0.426	19%
25	Mississippi	0.473	0.485	2.7%	0.512	0.652	27%
26	Missouri	0.449	0.455	1.2%	0.396	0.457	15%
27	Montana	0.488	0.444	(9.0%)	0.330	0.413	25%
28	Nebraska	0.463	0.456	(1.7%)	0.389	0.397	2.0%
29	Nevada	0.463	0.512	11%	0.306	0.437	43%
30	New Hampshire	0.433	0.448	3.3%	0.249	0.323	30%
31	New Jersey	0.443	0.465	4.9%	0.380	0.439	15%
32	New Mexico	0.476	0.481	1.1%	0.463	0.546	18%
33	New York	0.441	0.457	3.7%	0.410	0.452	10%
34	North Carolina	0.446	0.451	1.1%	0.374	0.449	20%
35	North Dakota	0.473	0.586	24%	0.314	0.317	1.0%
36	Ohio	0.428	0.448	4.6%	0.353	0.386	9.4%
37	Oklahoma	0.472	0.493	4.5%	0.417	0.433	3.8%
38	Oregon	0.465	0.453	(2.5%)	0.346	0.432	25%
39	Pennsylvania	0.431	0.453	5.1%	0.313	0.418	34%
40	Rhode Island	0.431	0.422	(2.0%)	0.291	0.303	4.3%
41	South Carolina	0.435	0.465	6.7%	0.358	0.478	34%
42	South Dakota	0.455	0.467	2.6%	0.335	0.336	0.4%
43	Tennesse	0.465	0.467	0.5%	0.381	0.499	31%
44	Texas	0.479	0.491	2.5%	0.454	0.501	10%
45	Utah	0.451	0.468	3.9%	0.401	0.411	2.6%
46	Vermont	0.519	0.426	(18%)	0.333	0.387	16%
47	Virginia	0.444	0.449	1.0%	0.362	0.399	10%
48	Washington	0.435	0.441	1.3%	0.347	0.361	4.1%
49	West Virginia	0.427	0.418	(2.1%)	0.346	0.425	23%
50	Wisconsin	0.452	0.470	4.0%	0.373	0.393	5.4%
51	Wyoming	0.479	0.490	2.4%	0.274	0.408	49%

Source: authors' calculations with 1985 and 1987 SOI databases and

the 1985 and 1987 NBER simulations of state personal income tax liabilities.

optimistic projections of persistently high taxes on capital gains realizations, have raised their top marginal tax rates. It is likely that these changes will reverse the deterioration in vertical and horizontal equity which we have captured.

I. Algebraic Statement of Index Numbers

To facilitate the algebraic treatment of the preceding vertical and horizontal equity concepts, let there be j = 1,...,m ordered effective tax rate classes, and i = 1,...,n ordered economic income classes for the first taxpayer, and let there be k = 1,...,m effective tax rates classes and h = 1,...,n ordered economic income classes for the second taxpayer in each comparison.

Let N_i^j be the number of taxpayers in the *ij* the economic income - effective tax rate class which is to be compared to N_h^k, the number of taxpayers in the *hk* economic income - effective tax rate class. Note that higher subscripts and superscripts indicate higher economic income and higher effective tax rates, and that j = k =1 is the lowest negative tax rate class.

The unweighted vertical index numbers can now be specified. The total number of vertical comparisons is as follows.

$$\alpha = \sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k=1}^{m}\sum_{h=1}^{n}{}_{h\neq i}\,[N_i^j N_h^k]$$

The unweighted progressive index is specified as follows.

$$\frac{1}{\alpha}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k<j}^{m}\sum_{h<i}^{n}(N_i^j N_h^k)$$

$$+\frac{1}{\alpha}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k>j}^{m}\sum_{h>i}^{n}(N_i^j N_h^k)$$

The unweighted proportional index number is given as follows.

$$\frac{1}{\alpha}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{h=1}^{n}{}_{h\neq i}\,(N_i^j N_h^j)$$

The unweighted regressive index is as follows.

$$\frac{1}{\alpha}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k<j}^{m}\sum_{h>i}^{n}(N_i^j N_h^k) +$$

$$\frac{1}{\alpha}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k>j}^{m}\sum_{h<i}^{n}(N_i^j N_h^k)$$

Next the weighted vertical index numbers are specified. Let Y_i^j be the average income in the cell containing taxpayers in the *ij* economic income - effective tax rate cell. We would prefer to use individual economic incomes in the empirical work, but cannot due to computational limitations, so we use the average income in a cell.

To deal with a comparison between a positive and a negative tax rate, we take a ratio of the tax rate *class ranks*

(or subscripts) rather that the ratio of the average tax rates in the classes themselves. To be consistent, we also use the ratio of class ranks in comparisons involving two positive tax rates as well as any comparison involving a zero tax rate.

The total of weighted vertical comparisons is specified as follows.

$$\Delta = \sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k=1}^{m}\sum_{h=1}^{n}{}_{h\neq i}\ [\,N_i^j N_h^k \max(\frac{j}{k},\frac{k}{j})|Y_i^j - Y_h^k|\,]$$

The weighted fraction of taxpayers whose tax liability is progressively distributed is obtained by accumulating across comparisons in which the effective tax rate and economic income classes of the second group of taxpayers are *smaller* than those of the first group of taxpayers ($k < j$, $h < i$), and by accumulating across comparisons in which the effective tax rate and economic income of the second group of taxpayers are *greater* than the first group of taxpayers ($k > j$, $h > i$).

Since tax rates vary now in these progressive comparisons, we weight the accumulation by the ratio of the ranks of tax rate classes discussed above. Note that in forming the weight for the tax-rate ratio, we always divide the larger rank by the smaller rank of effective tax rates to insure that comparisons are treated symmetrically. Since the first group of comparisons always entails $k < j$, we form the weight as j/k; similarly, since the second group of progressive comparisons always entails $k > j$, we form the weight as k/j.

Thus, we have:

$$\frac{1}{\Delta}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k<j}^{m}\sum_{h<i}^{n}(N_i^j N_h^k)(\frac{j}{k})|Y_i^j - Y_h^k|$$

$$+\frac{1}{\Delta}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k>j}^{m}\sum_{h>i}^{n}(N_i^j N_h^k)\frac{k}{j}|Y_i^j - Y_h^k|$$

We obtain our measure of the extent to which taxes are proportionately distributed among pairs of taxpayers with different incomes by making all *possible* paired comparisons of taxpayers with different economic income ($i \neq h$), and then add up the number of such proportional comparisons from different effective tax rate classes to the total number of proportional comparisons. Normalization by the sum of weighted comparisons, Δ, provides the fraction or percentage of comparisons which is proportionately distributed:

$$\frac{1}{\Delta}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{h=1}^{n}{}_{h\neq i}(N_i^j N_i^k\,|Y_i^j - Y_i^k|)$$

The fraction of taxpayers whose tax liability is regressively distributed is obtained by accumulating in the same manner as was used in calculating the fraction of taxpayers whose tax liability is progressively distributed, *except*

that in accumulating for this index number, k < j and h > i in the first accumulation, and k > j and h < i in the second accumulation. That is, for the comparison to be *regressive*, the second group of taxpayers either has a lower effective tax rate and greater economic income, *or* higher effective tax rate and lower economic income than the first group of taxpayers. Since in the first accumulation the effective tax rate of the second group of taxpayers is lower than the first group of taxpayers, our tax rate weight for regressivity is formed as j/k. Similarly, since in the second accumulation the effective tax rate of the second group of taxpayers is greater than the first group of taxpayers, our tax rate weight is formed as k/j. We have, then:

$$\frac{1}{\Delta}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k<j}^{m}\sum_{h>i}^{n}(N_i^j N_h^k)\frac{j}{k}|Y_i^j - Y_h^k| +$$

$$\frac{1}{\Delta}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k>j}^{m}\sum_{h<i}^{n}(N_i^j N_h^k)\frac{k}{j}|Y_i^j - Y_h^k|$$

We move next to give formulae for the unweighted horizontal equity index numbers. The total count of horizontal comparisons is given by the following expression.

$$\beta=\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k=1k\neq j}^{m}[N_i^j N_i^k]+\sum_{j=1}^{m}\sum_{i=1}^{n}[N_i^j(N_i^j-1)]$$

The unweighted horizontal inequity index is given by the following expression.

$$\frac{1}{\beta}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k=1_{k\neq j}}^{m}[N_i^j N_i^k]$$

The unweighted horizontal equity index is simply the difference between 1 and this fraction.

With respect to the algebraic statement of the weighted index of horizontal equity, recall first that the economic income of two taxpayers in the same horizontal comparison is close. That is, all analysis is done *within* each economic income class (i = h). As a consequence, there can be no differences in economic income to weight by, and only differences in effective tax rates are of interest in accumulating instances of horizontal inequity. We may then compactly define the fraction of taxpayers with the same economic income but different effective tax rates, instances of horizontal inequity as:

$$\frac{1}{\delta}\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k=1_{k\neq j}}^{m}[N_i^j N_i^k \max(\frac{j}{k},\frac{k}{j})]$$

where the sum of all horizontal comparisons, δ, is:

$$\delta=\sum_{j=1}^{m}\sum_{i=1}^{n}\sum_{k=1k\neq j}^{m}[N_i^j N_i^k \max(\frac{j}{k},\frac{k}{j})]+\sum_{j=1}^{m}\sum_{i=1}^{n}[N_i^j(N_i^j-1)]$$

Note that the second term represents the number of comparisons in which the effective tax rates and economic

income classes are the same (j = k), (i = h). A total of N_i^{j2} comparisons are possible; however, in order to avoid comparisons of individuals with themselves, there remains $N_i^j(N_i^j\text{-}1)$ comparisons. The difference between 1 and the unweighted horizontal inequity index is our measure of horizontal equity, and differs from that suggested by Wertz [1975] in that the *extent* of effective tax rate differences are accounted for by weighting using the ratio of relative ranks.

Finally, we specify formally the (unweighted) dynamic vertical index numbers. Let q be the number of classes of ratios of effective rates. Of course, this can differ in number and classification from the classifications of the effective rates themselves. Let D_i^j be the number of taxpayers in economic income class i and *change* in effective tax rate class j. Recall that the unweighted count of vertical comparisons is α. The dynamic progressive index number is given by the following formula.

$$\frac{1}{\alpha}\sum_{j=1}^{q}\sum_{i=1}^{n}\sum_{k<j}^{q}\sum_{h<i}^{n}(D_i^j D_h^k)$$

$$+\frac{1}{\alpha}\sum_{j=1}^{q}\sum_{i=1}^{n}\sum_{k>j}^{q}\sum_{h>i}^{n}(D_i^j D_h^k)$$

The dynamic proportional index number is given as follows.

$$\frac{1}{\alpha}\sum_{j=1}^{q}\sum_{i=1}^{n}\sum_{h=1_{h\neq i}}^{n}(D_i^j D_h^j)$$

The dynamic regressive index is as follows.

$$\frac{1}{\alpha}\sum_{j=1}^{q}\sum_{i=1}^{n}\sum_{k<j}^{q}\sum_{h>i}^{n}(D_i^j D_h^k) +$$

$$\frac{1}{\alpha}\sum_{j=1}^{q}\sum_{i=1}^{n}\sum_{k>j}^{q}\sum_{h<i}^{n}(D_i^j D_h^k)$$

Key to Symbols:

n = # of economic income classes
a = # of after-tax income classes
m = # of effective rate classes
N_i^j = population in economic income class i, rate class j
Y_i^j = average income in economic income class i, rate class j
Z_i = average income in after-tax income class i
P_i = population in after-tax income class i
POP = total population
INC = total after-tax income

Below, we provide algebraic statements of a variety of other index numbers from the literature in notation consistent with that used to describe the various index numbers which are empirically implemented in this paper. Due to space limitations, the empirical results for these index numbers across the various experiments are not included in this paper. They are, however, available from the authors upon request.

(6) = INC/POP

(7) = $\frac{1}{POP}\sum_{i=1}^{a}(Z_i - AVINC)^2 * P_i$

(8) = $\sqrt{VAR}/AVINC$

(9) = $\frac{1}{POP}^2 \sum_{i=1}^{a}\sum_{j=1}^{i-1} P_i * P_j * |Z_i - Z_j|$

(10) = $MD/AVINC$

(11) = $GINI/2$

(12) = $\frac{1}{AVINC * POP * (POP-1)} \sum_{i=1}^{a}\sum_{j=1}^{i-1} |Z_i - Z_j| * P_i * P_j$

(13) = $1 - [\sum_{i=1}^{a}(\frac{1}{AVINC})^{1-\varepsilon}\frac{1}{POP}]^{\frac{1}{1-\varepsilon}}$

(14) = $1000 * \log(\sum_{i=1}^{a} \exp[(AVINC - Z_i) * \frac{1}{1000}]\frac{P_i}{POP})$

(15) = $\frac{1}{POP}\sum_{i=1}^{m}|\frac{Z_i}{AVINC} - 1| * P_i$

(16) = $RMD1/2$

$X_i = Z_i/INC$

(17) = $\sum_{i=1}^{a} P_i * X_i * \log(X_i)$

(18) = $\sum_{i=1}^{a} P_i * Z_i * \log(POP * Z_i)$

(19) = $\frac{1}{POP}\sum_{i=1}^{a} \mathrm{Sign}(Z_i) * P_i * \log(|Z_i|)$

(20) = $\frac{1}{POP}\sum_{i=1}^{a} P_i * (\log(|Z_i/AVINC|))^2$

(21) = $\frac{1}{POP}\sum_{i=1}^{a} (\mathrm{Sign}(Z_i) * \log(|Z_i|) - THEIL3)^2 * P_i$

(22) = $\sum_{i=1}^{a} P_i * |\frac{Z_i}{INC} - \frac{1}{POP}| = RMD1$

(23) = $\frac{1}{POP}\sum_{i=1}^{n}\{[\frac{\sum_{j=1}^{m} N_i^{j2}}{\sum_{j=1}^{m} N_i^j * j}] * [\frac{\sum_{j=1}^{m}\sum_{k=j+1}^{m}(j-k)^2 * N_i^k * N_i^j}{\sum_{j=1}^{m}\sum_{k=j+1}^{m}(N_i^k * N_i^j) + \frac{1}{2}\sum_{j=1}^{m} N_i^j * (N_i^j - 1)}]^{\frac{1}{2}}\}$

Key to Equations:

# of Eq.	Index Number	Reference
(6) =	Average after-tax income	
(7) =	Variance	Kondor 1975
(8) =	Coefficient of variation	Atkinson 1970; Fields and Fei 1978
(9) =	Mean difference	Kendall 1947
(10) =	Gini coefficient	Pyatt 1976
(11) =	Atkinson Gini	Atkinson 1970
(12) =	Coefficient of concentration	Kondor 1975
(13) =	Atkinson	Atkinson 1970 AT1: $\varepsilon = .3$ AT2: $\varepsilon = .7$
(14) =	Kolm	Kolm 1976
(15) =	Relative mean deviation #1	Atkinson 1970
(16) =	Relative mean deviaiton #2	Kondor 1975
(17) =	Theil #1	Bourguignon 1979
(18) =	Theil #2	Fields and Fei 1979; Theil 1967
(19) =	Theil #3	Theil 1967
(20) =	Standard deviation of logarithms	Atkinson 1970
(21) =	Logarithmic variance	Kondor 1975
(22) =	Kuznets ratio	Fields and Fei 1979
(23) =	Average coefficient of variation of effective rates	

7. References

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