Enforcement Costs and the Optimal Progressivity of Income Taxes

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1. INTRODUCTION

The U.S. President's Council of Economic Advisors heralded the passage of the Tax Reform Act of 1986 with the remarks:

> Lower marginal tax rates on personal income, in conjunction with a broader tax base, will increase labor effort and reduce the exploitation of tax loopholes. . . . [H]igh marginal tax rates increase incentives to engage in tax avoidance and evasion.[1]

Mirrlees, Sheshinski, Atkinson, Feldstein, Stern, Hellwig, and others have analyzed the balance between redistribution and production of income in setting marginal tax rates. These studies indicated that the trade-off would resolve to optimal marginal tax rates substantially below 100 percent.

Recently, attention has turned to the effect of marginal tax rates on evasion (Townsend; Sandmo; Graetz and Wilde; Mookherjee and Png, 1989a; Sanchez and Sobel). In this line of work, a revenue collector can enforce compliance with tax law by expending resources to audit taxpayers' reports. The more progressive the income tax, however, the more tempted will a taxpayer be to evade, and hence the more auditing will be required to

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1. *Annual Report of the Council of Economic Advisors*, U.S. Government Printing Office, Washington, D.C. (1987:79, 83).

induce taxpayers to comply.[2] Accordingly, a social planner must weigh the additional enforcement cost against the redistributive benefits of more progressive taxes.

This research has shown that, *inter alia*, auditing should be random and the government should reward taxpayers who are verified to have reported truthfully.[3] It, however, has provided very little more specific guidance on the appropriate structure of taxes and enforcement policies. For instance, Mookherjee and Png (1989a) show that taxpayers with the highest income should pay the highest tax and enjoy the most consumption, but they do not provide any further general results.

In this article, we remove two unrealistic and implausible features of these general settings, and then explore the properties of the more realistic model. First, we believe that governments may be limited to policies that provide taxpayers with identical incomes who submit identical reports with identical (posttax) consumption ("horizontal equity").[4] Horizontal equity rules out the payment of rewards to taxpayers who are verified in an audit to have reported truthfully.

Furthermore, we contend that considerations of fairness and of marginal deterrence with respect to other crimes may dictate that penalties for tax evasion be graduated according to the severity of crime committed ("proportionality"). For instance, in U.S. civil proceedings, the Internal Revenue Code of 1986, as amended, specifies fines of up to 5 percent of the evaded tax plus interest in cases of negligence [§6653(a)], and fines of up to 75 percent plus interest for fraud [§6653(b)].

Accordingly, we limit the planner to schemes that meet horizontal equity and to proportional fines. For simplicity, we ignore the effect of marginal tax rates on labor effort and legal tax avoidance. In our model, risk-averse individuals differ in their (exogenous) income, and the planner seeks to maximize social welfare subject to raising some target revenue. The government has authority to require each individual to report his income, and condition transfers and audit enforcement on these reports. Auditing is without error. Using this model, we aim to describe the optimal structure of taxes and audit enforcement policy, and to consider how these vary with individual risk aversion, the cost of audit, and the rate of fines for tax evasion.

Unfortunately, the problem at hand, like most principal–agent models of auditing even when drastically simplified, does not yield significant analytical comparative statics results. To explore the problem further, we assumed a

2. For empirical evidence of the effect of tax rates on compliance, see Clotfelter, Crane and Nourzad, Alexander and Feinstein, Alm, Bahl, and Murray, and Feinstein.

3. Border and Sobel establish similar results for a principal seeking to maximize revenue from risk-neutral agents.

4. Atkinson and Stiglitz (pp. 391–92), Stiglitz, and Ortuno-Ortin and Roemer discuss the role of constraints of horizontal equity.

utilitarian welfare function and, following Feldstein and Stern, confined attention to linear income taxes, and numerically computed the optimal schemes of tax and audit enforcement for reasonable values of the parameters.[5] We drew on U.S. data for the distribution of income, poverty level (which defines a minimum level of household consumption), Federal government expenditure, and audit costs of the Internal Revenue Service. We postulated individual taxpayers to have (constant) relative risk aversion varying between 0.25 and 6, a range that includes most empirical estimates.

Several of the results surprised us. For all reasonable values of the parameters, the optimal marginal tax rate exceeded 90 percent. Moreover, the rate was quite insensitive to considerable variation in personal risk aversion, poverty level, audit costs, and penalty rates.[6] For each set of parameter values, a high marginal tax rate was coupled with a large lump-sum subsidy. This very progressive tax structure required substantial auditing. These calculations suggest that calls to cut marginal tax rates in order to reduce tax evasion must be treated with caution. For realistic parameter values, the audit costs of enforcing more progressive taxes may be outweighed by the corresponding benefits in terms of redistribution and social insurance.

Border and Sobel showed that a principal seeking to maximize revenue from risk-neutral agents should audit reports of higher incomes less frequently. Our calculations indicate that this result does not apply to the problem of redistribution that we pose. In our setting, the audit rate may *rise* with reported income essentially because proportional penalties deter large-scale evasion much more vigorously than minor underreporting. Hence, to compel truthful reporting, reports of intermediate levels of income must be audited more frequently than reports of the lowest incomes.

A shift to a higher penalty rate did not necessarily raise the optimal marginal tax rate. Indeed, in many instances, an increased penalty rate was associated with a *lower* optimal tax rate—because, as Yitzhaki (1974) showed, a higher marginal tax rate raises the amount of tax evaded for a given degree of underreporting of *income*, and thereby enhances the penalty for evasion. Consequently, a higher marginal tax rate, by enhancing penalties, will itself deter evasion and tend to *reduce* the cost of enforcement.[7] Accordingly, at a low penalty rate, an increase in the marginal tax rate raises

5. Feldstein and Stern took this approach to study the trade-off between effort incentives and redistribution of income. Their focus on linear taxes may be justified, in part, by Mirrlees' finding from numerical calculations that the optimal nonlinear tax schedule was very close to being linear. In related work, Townsend numerically computes solutions to a general principal–agent formulation of auditing. Our emphasis is less methodological than Townsend's, and we impose horizontal equity, proportionality, and linear taxes on the problem.

6. Clearly, the marginal tax rate would have been still higher if the welfare function exhibited greater aversion to inequality than a utilitarian one.

7. This effect has been noted by other researchers including Klepper, Nagin, and Spurr.

welfare both by reducing enforcement costs, *and* by enhancing redistribution. For higher penalty rates, the effective penalty is limited by the constraint that each taxpayer receive at least the poverty level; hence, a higher marginal tax rate benefits the social planner only through redistribution.

The structure of the paper is as follows. In Section 2, we develop the basic model and investigate general properties of optimal nonlinear schemes of taxes and audit enforcement. This analysis, however, indicates the difficulty of answering more detailed comparative-statics questions by analytical methods alone. Accordingly, we explore these through numerical computations of optimal linear tax schemes in Section 3 and, finally, present concluding remarks in Section 4.

2. MODEL

Individuals differ only in their income level, which may take one of n possible values, $Y_1, Y_2, \ldots, Y_n$, where $0 < Y_{i-1} < Y_i$, for all $i \geq 2$. Let an exogenous λ_i proportion of the population have income Y_i, and without loss of generality, $\lambda_i > 0$, for all i, and $\Sigma_{i=1}^{n} \lambda_i = 1$. Each individual knows his own income but the government does not. The government, however, may expend resources to discover a person's true income without error. We assume that the government incurs a resource cost of A_i to audit an individual with true income Y_i.[8] All persons have the identical continuous, strictly increasing, and concave Neumann–Morgenstern utility function $U(\cdot)$ defined over consumption.

In this section, we assume that the government aims to maximize an individualistic additively separable social-welfare function. This formulation permits the government's objective to be represented either by an ex ante or an ex post social-welfare function. We adopt the latter approach.[9] The government has authority to require all individuals to submit reports regarding their income, to levy taxes according to the taxpayers' reports, to audit selected reports, and to impose monetary penalties that depend on both the taxpayer's true income and report.

We believe, however, that the government may be restricted in the extent to which it may employ these instruments. First, there may be a poverty level, $\underline{C}$, beyond which the government may not tax or fine a taxpayer.

8. Our analysis extends to the case where the individual also incurs a (commonly known) cost from being audited. In that case, A_i should be viewed as the sum of the costs incurred by the government and the individual. The allocation of audit costs between them is irrelevant as transfers between them can occur subsequent to an audit. Under the restriction of horizontal equity that we will impose below, a taxpayer verified to have reported truthfully should be reimbursed for audit costs incurred by him.

9. See Hammond for a discussion of alternative welfare objectives in the presence of uncertainty. In subsequent sections, we specialize to a utilitarian welfare function, in which case, the ex ante and ex post approaches coincide.

Second, the government may be limited to tax structures and audit enforcement policies that provide equal consumption to taxpayers with identical income who send identical reports. This condition of horizontal equity rules out randomized taxes and randomized penalties. It also excludes rewards to individuals who are verified to have reported truthfully—because such rewards would give higher consumption to individuals whose reports are audited compared to otherwise identical taxpayers whom the government does not audit.[10] Third, legal and social norms may dictate that penalties be set proportionally. Accordingly, and also to reflect current practice, we postulate that penalties recover unpaid taxes plus a fixed proportion f of taxes evaded, subject to providing the taxpayer with the minimum consumption, $\underline{C}$.

Many problems of mechanism design can be simplified by using the Revelation Principle.[11] In the present setting, the taxpayer's information is verifiable, there are restrictions on permissible messages, and the mechanism must satisfy horizontal equity. Accordingly, it is not *a priori* obvious that the Revelation Principle applies. Indeed, Stiglitz (1982) showed that a utilitarian planner may prefer to introduce randomized policies in the presence of incentive constraints. Hence, if the planner is restricted to deterministic policies, it may be desirable to induce taxpayers to choose randomized (or asymmetric) reporting strategies to realize the "efficiency" benefits of asymmetric treatment of taxpayers, in which case taxpayers will not always be induced to report truthfully.

We show in Appendix A, however, that the Revelation Principle does indeed apply in this context.[12] Accordingly, let the government choose a structure of taxes, $\{T_i\}$, where an individual reporting income Y_i must pay tax T_i, and an enforcement policy, $\{p_i, F_{i,Y_j}\}$, where reports of income Y_i will be audited with probability p_i, and every individual with true income Y_j who reports Y_i and is audited will be fined an amount F_{i,Y_j}. By the Revelation Principle, the government may restrict attention to schemes of taxes and audit enforcement that induce each taxpayer to report his income truthfully.

Consider a taxpayer with income Y_j who reports truthfully. He will receive consumption of $Y_j - T_j - F_{j,Y_j}$ if the government audits his report, and consumption of $Y_j - T_j$ otherwise. Horizontal equity requires that the government not impose any additional transfer if an audit shows the taxpayer to have reported truthfully (i.e., $F_{j,Y_j} = 0$). Hence, the consumption of such an individual will be simply $Y_j - T_j$.

10. Horizontal equity, however, does not constrain the planner to treat identical taxpayers identically off the equilibrium path.

11. This principle states that the government may restrict attention to mechanisms where taxpayers are asked to report their incomes and are provided with incentives to report truthfully. See Harris and Townsend.

12. See, also, Border and Sobel, Melumad and Mookherjee, and Ortuno-Ortin and Roemer.

What if the taxpayer with income Y_j (falsely) reports income Y_i? If he is not audited, he will have consumption of $Y_j - T_i$. Since he will not report an income that would force his consumption below the poverty level, we restrict the possible false reports to Y_i such that $Y_j - T_i \geq \underline{C}$. If the government does audit his report, it will discover that he dissembled, and fine him an amount F_{j,Y_i} (including the amount of underpaid taxes). In equilibrium, all taxpayers report truthfully; hence, horizontal equity does not restrict the fines, F_{j,Y_i}, $i \neq j$, off the equilibrium path. By the proportionality postulate, the penalty for false reporting will be set at $(1 + f)(T_j - T_i)$, subject to providing the minimum consumption, $\underline{C}$. Accordingly, the consumption of the taxpayer who dissembles will be

$$\max[\underline{C}, Y_j - T_j - f(T_j - T_i)]. \tag{1}$$

Thus the government aims to choose a scheme of taxes and audit enforcement, $\{T_i, p_i\}$, to maximize

$$\sum_{i=1}^{n} \lambda_i W(U(Y_i - T_i)) \tag{2}$$

subject to the revenue constraint

$$\sum_{i=1}^{n} \lambda_i (T_i - p_i A_i) \geq R; \tag{3}$$

the incentive constraints to ensure that each taxpayer will report truthfully,

$$U(Y_j - T_j) \geq p_i U\{\max[\underline{C}, Y_j - T_j - f(T_j - T_i)]\} + (1 - p_i) U(Y_j - T_i), \tag{4}$$

for all i such that $Y_j - T_i \geq \underline{C}$, for all j; the constraints that consumption not fall below the poverty level,

$$Y_j - T_j \geq \underline{C}, \tag{5}$$

for all j; and the constraints that the p_j be probabilities,

$$1 \geq p_j \geq 0, \tag{6}$$

for all j.

By (5), $Y_i > T_i$, for all i, and by (3),

$$T_i \geq \frac{1}{\lambda_i}\left[R - \sum_{j\neq i} \lambda_j (T_j - p_j A_j)\right] > \frac{1}{\lambda_i}\left[R - \sum_{j\neq i} \lambda_j Y_j\right],$$

for all i, since $Y_j > T_j, p_j \geq 0$, and $A_j \geq 0$, all j. We assume that R is small enough to ensure that the feasible set is nonempty. Since the feasible set is bounded, there will exist a solution to the problem.

Proposition 1. If the optimal tax structure is $\{T_i\}$, the optimal audit policy is

$$p_i = \max_{\{j|T_j > T_i\}} \left\{ \frac{U(Y_j - T_i) - U(Y_j - T_j)}{U(Y_j - T_i) - U[\max(\underline{C}, Y_j - T_j - f(T_j - T_i))]} \right\}, \quad (7)$$

$i = 1,\ldots,n$.

Proof. At any solution to the problem of maximizing (2) subject to (3)–(6), the revenue constraint must bind; otherwise, the problem is to maximize (2) subject to (4)–(6). However, the latter problem has no solution, as we can choose a lump-sum tax policy $T_i = T_j = T$, for all i, j, and let T be arbitrarily small.

This implies that given the tax structure $\{T_i\}$, the optimal audit policy must minimize the aggregate cost of audit $\Sigma_{i=1}^{n} \lambda_i p_i A_i$ subject to the incentive constraints (4). From (4),

$$p_i\{U(Y_j - T_i) - U[\max(\underline{C}, Y_j - T_j - f(T_j - T_i))]\} \\ \geq U(Y_j - T_i) - U(Y_j - T_j),$$

for all j such that $T_i \leq Y_j - \underline{C}$. If $T_j \leq T_i$, then $U(Y_j - T_i) - U(Y_j - T_j) \leq 0$; hence, the constraints are satisfied even with $p_i = 0$. Thus, the constraints apply only if $T_j > T_i$, which implies that $T_i < Y_j - \underline{C}$, since by (5), $T_j \leq Y_j - \underline{C}$. The result then follows immediately. ■

This recursive structure of optimal tax-audit schemes suggests how to delegate enforcement and collection of income taxes. Once the government has chosen the tax structure, it should direct the revenue-collecting agency to enforce the given tax scheme at minimum audit cost.

Proposition 1 also implies that the optimal audit enforcement policy will have the following two features.

(a) *If every taxpayer obtains consumption greater than the poverty level, optimal audits are random* (i.e., $p_i < 1$, for *all* i). If reports of some income, Y_i, were audited with certainty, every taxpayer with a different income, Y_j, would strictly prefer not to misreport Y_i as they would certainly be discovered and penalized. Consequently, the frequency of audit may be reduced below 1 while preserving incentives for truthful reporting.[13]

(b) *Reports of incomes for which the tax is highest need not be audited* (*i.e., if* $T_k \geq T_i$, *for all* i, *then* $p_k = 0$). All other reports must be audited with positive probability.

In light of Proposition 1, the government's problem simplifies to choosing $\{T_i\}$ to maximize

$$\sum_{i=1}^{n} \lambda_i W(U(Y_i - T_i)) \tag{2}$$

subject to the revenue constraint

$$\sum_{i=1}^{n} \lambda_i T_i \geq R + \sum_{i=1}^{n} \lambda_i A_i \max_{\{j|T_j > T_i\}} \left\{ \left[U(Y_j - T_i) - U(Y_j - T_j) \right] \left[U(Y_j - T_i) - U[\max(\underline{C}, Y_j - T_j - f(T_j - T_i))] \right]^{-1} \right\}, \tag{8}$$

and the minimum constraints on consumption,

$$Y_i - T_i \geq \underline{C}, \tag{5}$$

for all i.

The expression for the enforcement cost is rather unwieldy, and cannot be characterized simply by a set of first-order conditions. One reason is that even if we restrict the government to structures of taxes that increase with income, the degree of progressivity of the taxes affects the identity of the higher-income taxpayers that are the most tempted to report (falsely) a given income level. In particular, our computations below show that the incentive constraints in (7) that bind need not be the local downward ones.

3. NUMERICAL COMPUTATION OF OPTIMAL LINEAR TAXES

In this section, we numerically compute optimal policies of taxation and enforcement for parameter values representative of the U.S. economy in 1986.[14] With these computations, we aim to study the trade-off between tax

13. This confirms Townsend's conjecture that random audits generally can induce taxpayers to report truthfully at lower cost than policies of deterministic auditing.

14. Please refer to Appendix B for a detailed description of the methods used in the computations.

progressivity and enforcement costs, and how this balance depends on penalty rates, risk-aversion of taxpayers, audit costs, and the poverty level. Our calculations should also throw light on the qualitative properties of optimal audit strategies (e.g., how audit rates should vary with reported income).

In order to facilitate interpretation and more reliable computation, we restrict the problem in several ways. First, we focus on linear income tax schedules, $T_i = -T + \beta Y_i$, where T is a lump-sum subsidy (interpreted as the size of the welfare system), and β is the constant marginal tax rate, $0 \leq \beta \leq 1$. Besides providing a simple measure of tax progressivity, this restriction to linear taxes significantly simplifies the task of checking the solutions generated by direct grid search over the parameter space.[15]

Second, we assume a utilitarian welfare function, and that all taxpayers have identical constant relative risk aversion, ρ, so that utility $U(C) = C^{1-\rho}/(1 - \rho)$. Kimball argues that reasonable values for ρ range between 1 and 6, while Hansen and Singleton estimated values between 0.264 and 2.721.[16] We compute results for values of ρ between 0.25 and 6.

Under these assumptions, taxes rise strictly with income; hence, the optimal audit probabilities (7) simplify to

$$p_i = \max_{\{j>i\}} \Big\{ \Big[(Y_j - \beta Y_i + T)^{1-\rho} - ((1-\beta)Y_j + T)^{1-\rho}\Big]\Big[(Y_j - \beta Y_i + T)^{1-\rho} - \max[\underline{C}, (1-\beta)Y_j + T - f\beta(Y_j - Y_i)]^{1-\rho}\Big]^{-1}\Big\}, \tag{9}$$

$i = 1,\ldots,n$. Further, the minimum consumption constraints, (5), become

$$(1 - \beta)Y_i + T \geq \underline{C},$$

$i = 1,\ldots,n$; hence, if the solution meets the constraint for $i = 1$, it will satisfy all the others as well. Substituting in (2), (8), and (5), the problem for a utilitarian government is to choose T and $\beta \in [0,1]$ to maximize

$$\frac{1}{1-\rho}\sum_{i=1}^{n} \lambda_i[(1 - \beta)Y_i + T]^{1-\rho}, \tag{10}$$

subject to the constraints on revenue,

15. In their numerical analysis of the trade-off between effort incentives and the welfare gains from tax progressivity, Feldstein and Stern also confined attention to linear tax schedules.

16. Hansen and Singleton obtained one estimate of −0.359, which they did not consider to be economically plausible.

$$T + \beta \sum_{i=1}^{n} \lambda_i Y_i \geq R + \sum_{i=1}^{n} \lambda_i A_i \max_{\{j>i\}} \Big\{ \Big[(Y_j - \beta Y_i + T)^{1-\rho} - ((1-\beta)Y_j + T)^{1-\rho} \Big] \Big[(Y_j - \beta Y_i + T)^{1-\rho} - \max[\underline{C}, (1-\beta)Y_j + T - f\beta(Y_i - Y_j)]^{1-\rho} \Big]^{-1} \Big\}, \tag{11}$$

and minimum consumption,

$$(1-\beta)Y_1 + T \geq \underline{C}. \tag{12}$$

We take the income distribution to be the U.S. household distribution of money income in 1986 as provided in the *Statistical Abstract of the United States: 1988*.[17] The *Statistical Abstract* gives the distribution by brackets of income; for each bracket, we take the midpoint as the income of every household within the bracket. Table 1 shows the computed distribution.

The distribution shows a total of 89,479,000 households. Also from the *Statistical Abstract* (p. 7; Table 2), the population of the United States in 1986 was 241.596 million; hence, the average household included 2.7 persons. We measure the minimum allowable consumption, $\underline{C}$, by the 1986 money-income poverty levels computed by the U.S. Social Security Administration, which were \$8737 for a household of three persons and \$11,203 for a household of four persons (*Statistical Abstract*, p. 406).

Total outlay of the Federal Government in 1986 was \$989.8 billion (*Statistical Abstract*, Table 472, p. 294); hence, we take the government revenue requirement per household to be R = \$11,060. From the *Budget of the United States Government, 1988*,[18] total Federal outlay on examinations by the Internal Revenue Service in 1986 was \$1.1395 billion to examine 1.310 million returns; hence, the average cost per return examined was \$870. As mentioned in the Introduction, under the Internal Revenue Code, penalties in civil proceedings range from 5 to 75 percent of the tax evaded. We consider values of the penalty rate, f, ranging from 0.1 to 0.6.

We adopted the following as a benchmark for most of our calculations: coefficient of risk aversion, $\rho = 1.25$; poverty level, $\underline{C}$ = \$8737; revenue target, R = \$11,060; audit cost independent of income level, $A_i = A$ = \$870, for all i; and penalty rate, $f = 0.3$.

In Table 2, we present solutions for penalty rates of 30 and 40 percent. Under both penalty rates, optimal tax schedules appear to be very progres-

17. U.S. Bureau of the Census, *Statistical Abstract of the United States: 1988*, 108th ed., Washington, D.C. (1987:422, Table 690).

18. Appendix to *Budget of the United States Government, 1988*, U.S. Office of Management and Budget, Washington, D.C.: U.S. Government Printing Office (1987:I-S21-25).

Table 1. U.S. Household Distribution of Money Income, 1986

	Annual Income, Thousand US$							
	2.5	7.5	12.5	17.5	22.5	30	42.5	100[a]
Proportion of households	0.074	0.117	0.110	0.104	0.096	0.166	0.165	0.168

Source: U.S. Bureau of the Census, *Statistical Abstract of the United States: 1988*, 108th ed., Washington D.C. (1987: 422, Table 690).
[a]The midpoint of the $50,000 and above income bracket was taken to be $100,000.

sive at all levels of risk aversion. Marginal rates of at least 93 percent are coupled with lump-sum subsidies exceeding $21,000, and substantially above the poverty level. Not surprisingly, these very progressive tax structures require substantial auditing; for instance, in the benchmark case of $f = 0.3$ and $\rho = 1.25$, reports of all but the highest income must be audited with frequencies exceeding 48 percent. By contrast, Mansfield reports that total Internal Revenue Service investigations and audits made up less than 2 percent of total returns filed in 1981.[19]

How do audit frequencies vary with reported income? Border and Sobel showed that a revenue-maximizing principal should audit reports of higher incomes less frequently. Further, Mookherjee and Png (1989b) prove the same result in a setting of redistribution through linear taxes similar to the present one, but in which the planner is permitted to penalize all evaders down to the poverty level without regard to the amount evaded.

Our calculations, however, indicate that this pattern does not generally apply when penalties are proportional; from Table 2, when $f = 0.4$ and $\rho = 1.25$, the audit frequency rises from 0.6671 for reports of income Y_3 to 0.6672 for reports of Y_4; and again, in the case of $f = 0.4$ and $\rho = 4$, the audit rate rises from 0.5913 for reports of Y_2 to 0.5914 for reports of Y_3. Indeed, with $f = 0.4$, the audit rate is almost constant with reported income over the lower four income brackets at all levels of risk aversion above 0.5.

This may be explained as follows. By (1), the consumption of every taxpayer with true income Y_j discovered to have falsely reported income Y_i will be reduced to

$$\max[\underline{C}, (1 - \beta)Y_j - f\beta(Y_j - Y_i) + T],$$

which *rises* with Y_i. Since the penalty for evasion increases with the extent of evasion, a taxpayer may be more tempted to evade a little than on a larger

19. Of course, these low audit rates might be justified by the substantially less progressive tax system in effect.

Table 2. Optimal Linear Tax and Audit Policy with $\underline{C}$ = 8737, R = 11,060, A = 870, and Penalty Rates f = 0.3 and f = 0.4

	ρ	0.25	0.50	0.75	1.25	1.5	2	4	6
f = 0.3	β	0.9685	0.9959	0.9951	0.9970	0.9961	1.000	0.9999	1.000
	$-T$	22,490	23,470	23,460	23,550	23,540	23,700	23,780	23,830
	p_1	0.7976	0.7598	0.7514	0.7392	0.7330	0.7206	0.6688	0.6152
	p_2	0.7902	0.7574	0.7514	0.7392	0.7331	0.7206	0.6658	0.6152
	p_3	0.7821	0.7574	0.7514	0.7392	0.7331	0.7206	0.6688	0.6132
	p_4	0.7733	0.7574	0.7514	0.7393	0.7331	0.7206	0.6688	0.6152
	p_5	0.7637	0.7518	0.7429	0.7246	0.7153	0.6962	0.6174	0.5373
	p_6	0.7557	0.7409	0.7262	0.6956	0.6801	0.6475	0.5162	0.3935
	p_7	0.7158	0.6810	0.6156	0.4803	0.4111	0.2925	0.0484	0.0066
	p_8	0	0	0	0	0	0	0	0
f = 0.4	β	0.9391	0.9653	0.9054	0.9056	0.9080	0.9988	1.000	1.000
	$-T$	21,470	22,420	23,500	23,540	23,640	23,700	23,830	23,800
	p_1	0.7757	0.7333	0.6921	0.6771	0.6695	0.6541	0.5913	0.5280
	p_2	0.7677	0.7257	0.6921	0.6771	0.6695	0.6541	0.5913	0.5280
	p_3	0.7590	0.7174	0.6922	0.6771	0.6695	0.6541	0.5914	0.5280
	p_4	0.7494	0.7085	0.6922	0.6772	0.6695	0.6542	0.5914	0.5280
	p_5	0.7390	0.6987	0.6815	0.6589	0.6474	0.6241	0.5297	0.4378
	p_6	0.7214	0.6822	0.6604	0.6227	0.6031	0.5641	0.4114	0.2820
	p_7	0.6850	0.6484	0.6154	0.4779	0.4127	0.2905	0.0481	0.0065
	p_8	0	0	0	0	0	0	0	0

scale. Accordingly, the authorities may need to audit reports of intermediate income levels *more frequently* than lower reports.[20,21]

3.1. Penalty Rates

Intuitively, one might think that stiffer penalties would reduce enforcement costs and, hence, lead the social planner toward a more progressive tax structure. Some of the solutions in Table 3 do exhibit this property—for instance, in the benchmark case of ρ = 1.25, the optimal marginal rate rises from 0.991 to 0.997 as the penalty rate rises from 0.5 to 0.6. Table 3, however, shows many more instances of the opposite effect—where the optimal marginal rate *falls* with the penalty rate; for example, in the benchmark case, the optimal β falls from 1.000 to 0.991 as f rises from 0.1 to 0.5.

When penalties are proportional, the absolute size of the penalty depends on the marginal tax rate. Yitzhaki proved that for a given degree of under-

20. By contrast, in Mookherjee and Png (1989b), every taxpayer who is discovered to have dissembled may be penalized down the poverty level, $\underline{C}$; hence, taxpayers are tempted to evade, if at all, to the maximum possible extent.

21. In the cases of f = 0.4 and ρ = 0.25, 0.5, the computations also show that each of the nonzero audit frequencies is determined by the incentive constraint to ensure that taxpayers with the highest income do not falsely report the respective lower income. This confirms that the local downward incentive constraints need not bind at the solution.

Table 3. Optimal Marginal Tax Rate, β, with $\underline{C}$ = 8737, R = 11,060, A = 870, and Alternative Penalty Rates

	Risk Aversion, ρ							
	0.25	0.5	0.75	1.25	1.50	2	4	6
Penalty rate, f								
0.1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.3	0.969	0.996	0.995	0.997	0.996	1.000	1.000	1.000
0.4	0.939	0.965	0.995	0.996	0.998	0.999	1.000	1.000
0.5	0.939	0.967	0.977	0.991	0.998	0.999	1.000	1.000
0.6	0.941	0.966	0.976	0.997	0.998	0.999	1.000	1.000

reporting of income, an increase in β raises the amount of taxes evaded, and thereby generates a *higher* penalty for tax evasion. Accordingly, when the penalty rate is low, a rise in β raises welfare both by reducing enforcement costs, *and* by enhancing redistribution. For higher penalty rates, the effective penalty is limited by the constraint that each taxpayer receive at least the poverty level; hence, a higher β benefits the social planner only through redistribution.

3.2. Risk Aversion

In a setting of redistribution through linear taxes similar to the present one but in which the planner is permitted to penalize all evaders down to the poverty level without regard for the amount evaded, Mookherjee and Png (1989b) show that higher risk aversion reduces the audit frequencies necessary to induce a truthful reporting under a given tax structure. Further, the higher is risk aversion, ρ, the greater the welfare benefit from redistribution. These two factors suggest that with a higher ρ, a higher degree of progressivity would be optimal.

Indeed, from Table 3, we see that, except when the penalty rate $f = 0.3$, the optimal marginal rate rises or is constant with ρ. When $f = 0.3$, the marginal rate first rises as ρ increases from 0.25 to 0.5, then oscillates as ρ increases to 1.50, and finally rises monotonically thereafter.

The latter observations might be explained by two countervailing factors. First, an increase in risk aversion, while reducing absolute enforcement costs, may raise the *marginal* enforcement cost associated with higher progressivity [*i.e.*, the cross-partial $\partial(\partial p_i/\partial\beta)/\partial\rho$ may be positive]. Second, the higher is ρ, the more sensitive the social-welfare function will be to variations in low values of consumption.[22] A lower marginal tax rate will require

22. Specifically, for small values of C, $U'(C) = C^{-\rho}$ is increasing in ρ. Moreover, as $\rho \to \infty$, the utility function approaches maxi-min.

Table 4. Optimal Linear Tax with ρ = 1.25, R = 11,060, f = 0.3, and Alternative Values of $\underline{C}$ and A

	Cost of Audit, A					
	870	1740	3480	870	1740	3480
Minimum consumption, $\underline{C}$	8737	8737	8737	11,203	11,203	11,203
Marginal tax rate, β	0.9970	0.9940	0.9879	0.9966	0.9932	0.9857
Lump-sum subsidy, $-T$	23,550	22,960	21,760	23,530	22,910	21,640

less audit expenditure, allowing the lump-sum subsidy to be increased, thereby increasing consumption for low-income individuals.

3.3. Audit Costs and Poverty Level

We also varied the audit cost and poverty level from the benchmark case. The solutions are displayed in Table 4. As might be expected, the optimal tax structure became less progressive with increases in either the cost of audit or the poverty level. Even with audit cost set at \$3480, being quadruple the average cost incurred by the Internal Revenue Service, and the poverty level set at the four-person household minimum of \$11,203, the optimal marginal rate exceeded 98 percent.

Second, we also considered how our results depended on the assumption of fixed audit costs. We assumed instead that the audit cost increased proportionately with reported income according to $A_i = 0.025Y_i$, $i = 1,\ldots,8$, which yields an average audit cost of \$870 as in the benchmark. The solutions in Table 5 also involve high optimal marginal rates. This should not be surprising as the results in Table 2 indicated that the audit frequency tended to fall with reported income. Under the assumption of proportional audit costs, the cost of auditing lower reports would fall relative to the cost of auditing higher reports. This would reduce the enforcement cost of supporting a higher marginal tax rate.

Table 5. Optimal Marginal Tax Rate, β, with $\underline{C}$ = 8737, R = 11,060, f = 0.3, and Fixed *vis-à-vis* Proportional Audit Costs

	Risk Aversion, ρ							
	0.25	0.5	0.75	1.25	1.50	2	4	6
Fixed audit cost	0.9685	0.9959	0.9951	0.9970	0.9961	1.000	0.9999	1.000
Proportional audit cost	0.9785	0.9918	0.9934	0.9962	0.9972	0.9979	1.000	1.000

4. CONCLUSION

Our calculations indicate that, for parameter values representative of the United States, the audit costs of enforcing compliance with very progressive taxes may be outweighed by the corresponding benefits in terms of redistribution and social insurance. Lower tax rates, however, may be justified on several other important grounds that we ignored in this analysis. High marginal tax rates discourage production of income, and lead taxpayers to expend resources in (legitimate) tax avoidance—for instance, in redirecting investments toward tax-favored activities. Moreover, we assumed that the government could audit individuals' incomes perfectly.[23] Accordingly, our calculations are merely a first step toward a complete understanding of the balance between tax progressivity and enforcement costs.[24]

In our setting, all taxpayers report truthfully; hence, auditing will not generate revenue. The results of Melumad and Mookherjee, however, suggest that the optimal audit enforcement policy can be induced through appropriate incentives for the collector of revenue, even if he cannot precommit to audit policies. Finally, our analysis is unabashedly normative: we ignored all political obstacles to the enactment of progressive taxes and large audit expenditures.

APPENDIX A: REVELATION PRINCIPLE

The government can generally design a *mechanism* consisting of (i) a set M of possible messages that each taxpayer is allowed to report; (ii) the tax T_m payable consequent on any given report $m \in M$; (iii) the probability p_m that a report of m will be audited; and (iv) the penalty F_{im} levied upon a taxpayer who reports m, is audited, and is discovered to have an income of Y_i. Given this mechanism, let q_{im} be the probability that a taxpayer with income Y_i reports m.[25] Further restrictions on feasible mechanisms are presented below.

Given a mechanism, $\langle M, \{T_m, p_m, F_{im}\}\rangle$, and associated taxpayers' reporting strategy, $\{q_{im}\}$, the expected level of social welfare is

23. On the issue of errors and ambiguities in the tax filing and audit process, see Scotchmer and Slemrod.

24. Graetz, Reinganum, and Wilde provide a positive analysis of these issues. Kaplow considers the trade-off between welfare distortions from commodity taxes and audit enforcement costs in a model where all consumers are risk neutral.

25. Alternatively, there is a large population of taxpayers that choose deterministic reporting strategies, and q_{im} is the fraction of taxpayers with income Y_i that report m.

$$\sum_{i=1}^{n} \lambda_i \sum_{m \in M} q_{im}[p_m W(U(Y_i - T_m - F_{im})) + (1 - p_m)W(U(Y_i - T_m))]. \tag{A1}$$

Hence, the government's problem is to design a mechanism that maximizes social welfare subject to several constraints. The first is that net revenue meet an exogenous target, R,

$$\sum_{i=1}^{n} \lambda_i \sum_{m \in M} q_{im}[T_m - p_m(A_i - F_{im})] \geq R. \tag{A2}$$

Second, the mechanism must provide all taxpayers with consumption at or above the poverty level. This means that for each Y_i, there must be a report $m \in M$ such that

$$Y_i - T_m \geq \underline{C} \quad \text{and} \quad Y_i - T_m - F_{im} \geq \underline{C}. \tag{A3}$$

Further, the strategy $\{q_{im}\}$ is an equilibrium reporting strategy for a taxpayer with income Y_i if, for all m such that $q_{im} > 0$,

$$[p_m U(Y_i - T_m - F_{im}) + (1 - p_m)U(Y_i - T_m)] \geq [p_{m'} U(Y_i - T_{m'} - F_{im'}) + (1 - p_{m'})U(Y_i - T_{m'})], \tag{A4}$$

for all $m' \in M$, such that $Y_i - T_{m'} - F_{im'} \geq \underline{C}$ and $Y_i - T_{m'} \geq \underline{C}$.

The fourth set of constraints ensures that audit probabilities lie between 0 and 1,

$$0 \leq p_m \leq 1, \tag{A5}$$

for all $m \in M$. Finally, we come to horizontal equity. This requires that taxes and penalties be deterministic. In addition there should be no discrimination between taxpayers with identical incomes who submit the same report according to whether their reports are audited. Hence,

$$F_{im} = 0, \tag{A6}$$

for all m, such that $q_{im} > 0$, for all i. Accordingly, the taxpayer's expected utility is $U(Y_i - T_m)$ in equilibrium. Off the equilibrium path, where $q_{im} = 0$, penalties are imposed according to $F_{im} = (1 + f)(T_i - T_m)$.

We next prove the following lemma.

Lemma (Revelation Principle). There will be no loss of welfare if the government restricts attention to the class of incentive-compatible revelation mechanisms; that is, where the message space consists only of the possible income levels, $M = \{Y_1, Y_2, \ldots, Y_n\}$, and tax structures and audit enforcement policies are such that every taxpayer will choose to report his income truthfully, $q_{im} = 1$ if and only if $m = Y_i$.

Proof. Consider any mechanism with message space, M, and scheme of taxes and audit enforcement, $\{T_m, p_m, F_{im}\}$, and associated reporting strategy $\{q_{im}\}$, that satisfy constraints (A2)–(A6). For each income Y_i, define $r(i) \in M$ by the property

$$r(i) \in \underset{\{m \in M | q_{im} > 0\}}{\operatorname{argmax}} \; [T_m - p_m A_i]. \tag{A7}$$

We now construct a revelation mechanism in the following way. Let $\hat{M} = \{Y_1, \ldots, Y_n\}$, and the tax-audit scheme be $\hat{T}_i = T_{r(i)}$, $\hat{p}_i = p_{r(i)}$, and $\hat{F}_{i,Y_j} = F_{i,r(j)}$. We claim that this mechanism, combined with truthful reporting by taxpayers, satisfies constraints (A2)–(A6), and provides a level of expected social welfare equal to that in the original mechanism.

The reporting strategy q_{im} in the original mechanism satisfies (A4). This implies that for all reports m such that $q_{im} > 0$,

$$U(Y_i - T_m) \geq p_{m'} U(Y_i - T_{m'} - F_{im'}) + (1 - p_{m'})\, U(Y_i - T_{m'}), \tag{A8}$$

for all $m' \in M$, such that $Y_i - T_{m'} - F_{im'} \geq \underline{C}$ and $Y_i - T_{m'} \geq \underline{C}$. By construction of $r(i)$, it follows that $q_{ir(i)} > 0$. Hence, for all reports m such that $q_{im} > 0$,

$$U(Y_i - T_m) = U(Y_i - T_{r(i)}) \equiv U(Y_i - \hat{T}_i) \tag{A9}$$

(i.e., a taxpayer with income Y_i, who reports truthfully in the revelation mechanism, receives utility exactly equal to that which he would receive under the original mechanism).

By the reporting constraints (A8),

$$\begin{aligned} U(Y_i - T_{r(i)}) &\geq p_{r(j)} U(Y_i - T_{r(j)} - F_{ir(j)}) + (1 - p_{r(j)}) U(Y_i - T_{r(j)}) \\ &\equiv \hat{p}_j U(Y_i - \hat{T}_j - \hat{F}_{i,Y_j}) + (1 - \hat{p}_j)\, U(Y_i - \hat{T}_j), \end{aligned}$$

if Y_j is such that $Y_i - \hat{T}_j - \hat{F}_{i,Y_j} \geq \underline{C}$ and $Y_i - \hat{T}_j \geq \underline{C}$. By substituting from (A9), it follows that under the revelation mechanism, the taxpayer with income Y_i will not prefer to report some $Y_j \neq Y_i$.

Thus, under the revelation mechanism, taxpayers of every income will report truthfully, and receive utility exactly equal to that which they would receive under the original mechanism. Hence, the revelation mechanism generates an equal level of social welfare.

$$\sum_{i=1}^{n} \lambda_i \sum_{m} q_{im} W(U(Y_i - T_m)) = \sum_{i=1}^{n} \lambda_i W(U(Y_i - \bar{T}_i)).$$

Since the revelation mechanism satisfies constraints (A3), (A5), and (A6), it remains only to prove that the revelation mechanism raises no less revenue.

By (A6), $\bar{F}_{ii} = F_{ir(i)} = 0$, since $q_{ir(i)} > 0$. Thus, the revenue raised by the revelation mechanism is

$$\sum_{i=1}^{n} \lambda_i[\bar{T}_i - \bar{p}_i(A_i - \bar{F}_{ii})] = \sum_{i=1}^{n} \lambda_i[\bar{T}_i - \bar{p}_i A_i].$$

By the definition of $r(i)$, for any m with $q_{im} > 0$, $\bar{T}_i - \bar{p}_i A_i = T_{r(i)} - p_{r(i)} A_i \geq T_m - p_m A_i$. By (A6), if $q_{im} > 0$, then $F_{im} = 0$ and it follows that

$$\sum_{i=1}^{n} \lambda_i[\bar{T}_i - \bar{p}_i(A_i - \bar{F}_{ii})] \leq \sum_{i=1}^{n} \lambda_i \sum_{m \in M} q_{im}[T_m - p_m(A_i - F_{im})]$$

(i.e., the revelation mechanism raises no less revenue). ■

APPENDIX B: PROCEDURE FOR COMPUTATION

The problem described by (10)–(12) has the following parameters: personal coefficient of risk aversion, ρ; poverty level, $\underline{C}$; audit cost, A_1; and penalty rate, f. For each setting of these parameters, we first used the Graves P-system, initialized at $T = 0$ and $\beta = 0.5$ to compute a candidate solution.[26] Welfare in all solutions was computed to six significant figures.

We next employed a simple grid search to obtain another candidate solution. Although (11) must bind with equality in a solution, this relation cannot be easily inverted to obtain a value for T as a function of β. Consequently, we had to construct a grid over both values of T and β. Since the P-system always produced T around −\$20,000, we felt that it would be prudent to restrict our search to T between 0 and −40,000. By assumption, $\beta \in [0,1]$.

The grid search proceeded as follows.

(i) Set the grid on T in steps of 100 and the grid on β in steps of 0.001;

26. Please refer to Brown, Graves, and Ronen for the programming method and FORTRAN code of the P-system.

denote the best five results (T_i,β_i), $i = 1,\ldots,5$, in decreasing order of welfare.

(ii) For each $i = 1,\ldots,5$, reset the grid on T to steps of 10 and the grid on β to steps of 0.0001, and search for the best five results in the range T between $T_i - 1000$ and $T_i + 1000$, and β between $\beta_i - 0.01$ and $\beta_i + 0.01$. Denote the best five results $(\hat{T}_j, \hat{\beta}_j)$, $j = 1,\ldots,5$, in decreasing order of welfare.

(iii) For each $j = 1,\ldots,5$, reset the grid on T to steps of 1 and the grid on β to steps of 0.00001, and search for the best five results in the range T between $\hat{T}_j - 50$ and $\hat{T}_j + 50$, and β between $\hat{\beta}_j - 0.0005$ and $\hat{\beta}_j + 0.0005$.

(iv) Select the best results from step 3.[27]

If the P-system's candidate solution yielded higher welfare (at six significant figures) than the candidate solution from the grid search, we accepted the solution of the P-system. If the P-system's candidate yielded lower welfare, we reran the P-system with the two variables initialized at the grid-search candidate. In all cases, the second run of the P-system generated the best candidate, which we accepted as the solution.

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27. The grid search for solutions to the problem with proportional audit costs generated substantially more feasible solutions; hence, in step (ii), we searched between $T_i \pm 500$ and $\beta_i \pm 0.005$, and in step (iii), between $\hat{T}_j \pm 30$ and $\hat{\beta}_j \pm 0.0003$.

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