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EVALUATING MINIMUM TAXATION

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Evaluating Minimum Taxation
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ABSTRACT

Minimum tax rules constrain only the lowest-tax jurisdictions. Because higher minimum tax rates expand the circle of affected countries and therefore the impact of any further changes, there can be dominated regions over which no parameter values would make a minimum tax efficient. Applying a Taylor approximation to the distribution of statutory corporate tax rates in 2020, the range 4%-27% is a dominated region: there may be an efficient minimum rate below 4%, or higher than 27%, but there is no efficient world minimum tax rate between 4% and 27%. Minimum taxes set at popular rates are particularly inefficient – a minimum tax rate of 15% yields value that, when positive, is equivalent to offsetting less than one percent of the effect of tax competition.

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1. Introduction.

Concern over the effects of tax competition increasingly prompts calls for minimum tax rules and other arrangements that would limit the scope of independent tax setting. The most prominent recent example is the worldwide corporate minimum tax proposed by the OECD (2021) and approved in concept by more than 100 countries. Other longstanding efforts include tax coordination initiatives by the European Union and minimum tax proposals for subnational jurisdictions such as U.S. states. These initiatives and others reflect ongoing interest in coordinated responses to tax competition pressures.

Tax coordination can address downward rate pressures from tax competition, but does so by requiring governments to adhere to collective rules that may be insensitive to differences in the situations and needs of individual jurisdictions. Minimum tax regimes are more flexible than complete harmonization, but nonetheless impose binding constraints on countries that otherwise would choose low tax rates. Furthermore, effective enforcement of a minimum tax agreement may require rules preventing governments from differentiating their taxation in ways that they would otherwise choose, such as by offering favorable taxation of highly valued economic activities or those located in economically depressed regions.

There are many reasons why business tax rates differ. The level and composition of a country's industrialization affects its perceived cost of business taxation and the relative attractiveness of alternatives such as personal income taxes and VATs. The distribution of income and likely incidence of business taxation also influence choices among tax alternatives. The political appeal of taxing business income differs widely, including among countries with similar economies and income distributions but different national politics. And countries differ in the extent to which their tax choices are influenced by international competition. As a result of these and other considerations, there are considerable differences in the rates at which countries tax business income.

This paper uses observed tax choices to evaluate the effects of minimum taxation. Minimum tax rules directly affect the tax rates of only those who would otherwise choose rates below the mandated minimum. An efficient minimum tax rate balances the consequences for all counties of a higher world average tax rate against the impact on countries whose tax rates are constrained by the minimum. Taylor approximations yield the rule that an efficient minimum tax rate equals the average tax rate of constrained countries plus the average effect of tax competition on all countries. Multiple points may satisfy this condition, since a higher minimum tax rate brings additional countries within its ambit, changing the average tax rate of affected countries, and readily generating additional points at which the effect of a higher world average tax rate might equal the impact on countries forced to increase theirs. This potential multiplicity of locally efficient minimum rates means that the globally efficient minimum tax rate may exhibit jumps, creating dominated regions over which no minimum tax rate is consistent with maximizing collective objectives, regardless of the effect of tax competition on tax rates.

The distribution of statutory corporate tax rates in 2020 is such that there appears to be a wide range of dominated minimum tax rates. Using GDP as a measure of relative willingness to pay, there is no tax competition scenario in which a world minimum tax rate between 4% and 27% is consistent with maximizing collective objectives. If tax competition otherwise depresses average tax rates by less than 4%, then the efficient minimum tax lies below 4%, whereas if tax competition depresses average tax rates by 4% or more, then a minimum tax rate of 27% or higher maximizes collective objectives. Alternative measures of relative willingness to pay produce similar ranges of dominated minimum tax rates; and there are analogous dominated tax rate regions for years prior to 2020. Dominated regions also appear when considering minimum effective corporate tax rates rather than minimum statutory rates.

Popular tax rates make particularly inefficient minimum tax rates. This follows from the envelope condition, which implies that requiring a country to change its tax rate ever so slightly does not impair its objectives. As a result, the (weighted average) cost of increasing the minimum tax rate is unusually low over ranges of tax rates that countries choose when unconstrained, since affected countries bear small costs of any mandated increases. If there are large enough concentrations of countries at certain tax rates, the marginal cost of increasing the minimum tax rate can decline so much that it falls below the marginal benefit – and that is why these are dominated regions, since it is inefficient to impose a minimum tax high enough to reach a concentrated tax rate region but not go beyond it.

Evidence for 2020 indicates that a world minimum statutory tax rate of 15% impairs collective objectives if tax competition reduces the average world tax rate by less than 5.7%. If the effect of tax competition exceeds 5.7%, then a world minimum tax rate of 15% advances collective objectives, but does so inefficiently, since 15% lies in the middle of a wide dominated region. There is no scenario in which a 15% minimum tax rate delivers an outcome that governments would value as much as offsetting just one percent of the effect of tax competition. For every case in which a 15% minimum tax rate advances collective objectives, a higher minimum tax rate, such as 28%, would do so much more effectively.

The tax rates that countries choose reveal their objectives; and the analysis in this paper uses these revealed preferences to evaluate the consequences of minimum taxation. The paper considers a minimum tax regime that would apply to all corporations, whereas the OECD (2021) world minimum tax proposal concerns only the taxation of large multinational companies. The OECD minimum tax proposal relies on financial accounting definitions of income, which differ from income definitions used by many tax systems currently; and legislated tax preferences can produce disconnects between average tax burdens and statutory tax rates. These and other differences between the OECD proposal and the setting considered by the paper means that the paper's numerical analysis need not bear exactly on the potential consequences of the OECD scheme – though it remains the case that any minimum tax regime may feature a wide range of dominated minimum tax rates, as appears to be the case for world corporate taxes in 2020.

2. *Minimum Taxes.*

In choosing tax rates, governments balance economic and political considerations that include not only revenue needs, the economic costs of different taxes, and desired distributions of tax burdens, but also competition with other governments.[1] It is useful to express the economic and political preferences of country *i* as a reduced form function of the country's own tax rate and the tax rates of other countries, or equivalently, a function $O_i\left(\tau_i, d_i\right)$ of country *i*'s own tax rate τ_i and the difference $d_i = \tau_i - \overline{\tau}$ between country *i*'s tax rate and the weighted average tax rate of all n countries, $\bar{\tau} = \sum \tau_i v_i$, with $\sum v_i = 1$. The weights used to construct $\bar{\tau}$ reflect the relative importance of the tax rates of different countries. Importantly, the relevant weighted average tax rate is taken to be the same for all countries, these common weights excluding the possibility that governments compare their tax rates to others chosen on idiosyncratic bases such as geographic or characteristic proximity. For analytical convenience, $O_i(\tau_i, d_i)$ is taken to be continuous and twice continuously differentiable in its arguments, with higher values of $O_i(\tau_i, d_i)$ corresponding to greater satisfaction of government objectives.

In the absence of world minimum taxation, countries are assumed to choose their tax rates to maximize their objectives, taking the world average tax rate to be unaffected by their own actions. The first order condition characterizing this behavior is

$$\frac{\partial O_i(\tau_i, d_i)}{\partial \tau_i} + \frac{\partial O_i(\tau_i, d_i)}{\partial d_i} = 0. \tag{1}$$

Equation (1) reflects that observed tax rates τ_i balance government tax rate preferences against their tax competition concerns.

2.1. Collective assessments.

Countries will typically differ in their preferred tax rates and perceived costs of deviating from the world average tax rate. As a result, any significant minimum tax effort is apt to further the objectives of some while thwarting the objectives of others, so an overall assessment requires a method of aggregating national outcomes. If tax rate preferences are embedded in broader objective functions $F_i\left[O_i(\tau_i, d_i) + y_i\right]$, with y_i a transferable commodity such as money, then $O_i(\tau_i, d_i)$ can be interpreted as willingness to pay for tax outcomes. With accompanying transfers of y, minimum taxation that increases the sum of $O_i(\tau_i, d_i)$ can be designed to further the objectives of every country. In the absence of such transfers, a natural aggregation is to take a weighted sum of national objectives, with weights w_i reflecting collective assessment of the

[1] Portions of the model setup draw from Hines (2023), which uses the same Taylor approximations to analyze the potential impact of tax harmonization.

relative importance of advancing the objectives of different governments. Weights are normalized so that $\sum w_i = 1$, with $w_i = 1/n$ if transfers of y are used to offset any distributional effects of collective tax measures. Independent tax setting produces a weighted sum S, given by $S = \sum O_i\left(\tau_i, d_i\right) w_i$.

2.2. Minimum taxation.

Minimum taxes partition the world into two endogenous groups: countries in group A, for whom the required minimum tax rate does not impose a binding constraint, and countries in group B, for whom it does. If τ_m is the minimum tax rate, then under a minimum tax regime every country in group B imposes that tax rate. Countries in group A impose tax rates $\hat{\tau}_i$ that are not directly affected by the minimum tax requirement but nonetheless may differ from the tax rates $\left(\tau_i\right)$ they choose in the absence of a minimum tax, since minimum taxes change world average tax rates, which then may influence tax choices. If tax rates are strategic complements, so countries react to higher tax rates elsewhere by increasing their own tax rates, then higher minimum tax rates will increase tax rates among unconstrained group A countries; and the opposite is the case if tax rates are strategic substitutes. A minimum tax rate τ_m produces a world average tax rate $\bar{\tau}_m$, with $\bar{\tau}_m = \sum_A \hat{\tau}_i v_i + \sum_B \tau_m v_i$.

Denoting the weighted sum of national objectives under a minimum tax by $M\left(\tau_m\right)$,

$$M\left(\tau_m\right) = \sum_A O_i\left(\hat{\tau}_i, \hat{\tau}_i - \bar{\tau}_m\right) w_i + \sum_B O_i\left(\tau_m, \tau_m - \bar{\tau}_m\right) w_i . \tag{2}$$

A minimum tax affects group B countries by directly constraining their tax choices; and it affects all countries by raising the world average tax rate. Evaluating a small change in the minimum tax rate by differentiating (2), and imposing the envelope condition that (1) holds for the group A countries whose tax rates are not constrained by the minimum, it follows that

$$M'\left(\tau_m\right) = -\frac{d\bar{\tau}_m}{d\tau_m} \sum \frac{\partial O_i}{\partial d_i} w_i + \sum_B \left(\frac{\partial O_i\left(\tau_m, \tau_m - \bar{\tau}_m\right)}{\partial \tau_i} + \frac{\partial O_i\left(\tau_m, \tau_m - \bar{\tau}_m\right)}{\partial d_i} \right) w_i . \tag{3}$$

2.3. Implications of nonstrategic tax choices.

If countries choose their tax rates independently of the tax rates of others – if $\frac{d\tau_i}{d\overline{\tau}} = 0$, so that tax rates are neither strategic complements nor strategic substitutes – then equation (3) can be readily analyzed. As noted in Appendix *A*, the absence of strategic interaction requires that $\frac{\partial^2 O_i}{\partial d_i^2} + \frac{\partial^2 O_i}{\partial \tau_i \partial d_i} = 0$, a condition that will be universally satisfied if $\frac{\partial^2 O_i}{\partial d_i^2} = \frac{\partial^2 O_i}{\partial \tau_i \partial d_i} = 0$. This and subsequent sections 3-5 consider this special case, as it affords the opportunity to identify the considerations that most directly bear on the evaluation of minimum taxation; section 6 generalizes the model to incorporate strategic tax rate interactions.

Tax competition continues to affect tax rate choices even in the absence of strategic complementarity or substitutability. This is evident from equation (1), which characterizes an objective-maximizing tax rate choice with two terms, the second of which, $\frac{\partial O_i}{\partial d_i}$, reflects the value that country *i* attaches to improving its competitive position relative to others. The assumption that $\frac{\partial^2 O_i}{\partial d_i^2} = \frac{\partial^2 O_i}{\partial \tau_i \partial d_i} = 0$ makes $\frac{\partial O_i}{\partial d_i}$ unchanging, but does not make it zero; and in the likely event that $\frac{\partial O_i}{\partial d_i} < 0$, competition puts downward pressure on tax rates, even though countries do not react to tax changes elsewhere.

In evaluating (3) it is helpful to take a first-order Taylor approximation to $\frac{\partial O_i\left(\tau_m, \tau_m - \overline{\tau}_m\right)}{\partial \tau_i}$, which yields

(4) $$\frac{\partial O_i\left(\tau_m, \tau_m - \overline{\tau}_m\right)}{\partial \tau_i} = \frac{\partial O_i\left(\tau_i, d_i\right)}{\partial \tau_i} + \frac{\partial^2 O_i\left(\tau_i, d_i\right)}{\partial \tau_i^2}\left(\tau_m - \tau_i\right).$$

With an unchanging value of $\frac{\partial O_i}{\partial d_i}$, (1) and (4) together imply that the second term on the right side of (3) can be expressed as

(5) $$\sum_B \left(\frac{\partial O_i\left(\tau_m, \tau_m - \overline{\tau}_m\right)}{\partial \tau_i} + \frac{\partial O_i\left(\tau_m, \tau_m - \overline{\tau}_m\right)}{\partial d_i} \right) w_i = \sum_B \theta_i \left(\tau_m - \tau_i\right) w_i ,$$

in which $\theta_i \equiv \frac{\partial^2 O_i\left(\tau_i, d_i\right)}{\partial \tau_i^2}$. The variable θ_i is a preference parameter that reflects the (assumed constant) rate at which country *i*'s valuation of a small tax change itself changes with the tax rate. Further defining $\tilde{\tau}_B \equiv \frac{\sum_B \tau_i \theta_i w_i}{\sum_B \theta_i w_i}$ to be the average tax rate of group *B* countries, weighted by $\theta_i w_i$, the right side of (5) becomes $\left(\tau_m - \tilde{\tau}_B\right) \sum_B \theta_i w_i$.

In interpreting the first term on the right side of (3), it is useful to consider the tax rate that maximizes country *i*'s objectives in the absence of international tax differences. This tax rate, denoted τ_i^*, is that which the government of country *i* would choose to maximize its objectives if it knew that it were a Stackelberg leader whose tax rate all other countries would mimic exactly. In this sense, τ_i^* is the tax rate that country *i* would choose in the absence of international competition. Since τ_i^* is an objective-maximizing rate, it must be that $\frac{\partial O_i\left(\tau_i^*, 0\right)}{\partial \tau_i} = 0$.

In practice, most countries do not impose tax rates that they would select in the absence of international competition; and tax rates certainly differ. A Taylor approximation to the value of $\frac{\partial O_i\left(\tau_i, d_i\right)}{\partial \tau_i}$ yields

(6) $$\frac{\partial O_i\left(\tau_i, d_i\right)}{\partial \tau_i} = \frac{\partial O_i\left(\tau_i^*, 0\right)}{\partial \tau_i} + \theta_i\left(\tau_i - \tau_i^*\right) = -\theta_i\left(\tau_i^* - \tau_i\right).$$

In applying (6), it is helpful to define Δ as the effect of tax competition on tax rates, the weighted difference between average tax rates chosen without regard to competition and average tax rates chosen in practice,

(7) $$\Delta \equiv \frac{\sum\left(\tau_i^* - \tau_i\right)\theta_i w_i}{\sum \theta_i w_i}.$$

The $\theta_i w_i$ weights used to calculate Δ generally track the importance of corporate tax rates in collective assessments, since countries with high values of $O_i\left(\tau_i, d_i\right)$ are apt to have high values of $\frac{\partial^2 O_i\left(\tau_i, d_i\right)}{\partial \tau_i^2}$. Equations (6) and (1) together imply that $\frac{\partial O_i\left(\tau_i, d_i\right)}{\partial d_i} = \theta_i\left(\tau_i^* - \tau_i\right)$; summing this equation, and applying (7), it follows that

(8) $$\sum \frac{\partial O_i\left(\tau_i, d_i\right)}{\partial d_i} w_i = \Delta \sum \theta_i w_i.$$

Equation (8) indicates that Δ is not only the average effect of tax competition on tax rates, but also the average extent to which countries care about changes to their competitive positions.

The first term in (3) is $\frac{d\overline{\tau}_m}{d\tau_m}$, the effect of the minimum tax on average tax rates. Appendix *A* shows that, in the absence of strategic reactions, $\frac{d\overline{\tau}_m}{d\tau_m} = \sum_B v_i$, reflecting that higher minimum taxes increase the tax rates only of group *B* countries. It is useful to introduce the measure $\psi \equiv \frac{\sum_B v_i / \sum v_i}{\sum_B \theta_i w_i / \sum \theta_i w_i}$, the ratio of group *B* weights used for tax rate comparison purposes to group *B* weights in collective objectives. Applying this definition, $\frac{d\overline{\tau}_m}{d\tau_m} = \psi \sum_B \theta_i w_i / \sum \theta_i w_i$, so together with (5) and (8), (3) becomes

(9) $$M'\left(\tau_m\right) = \left[-\sum_B \theta_i w_i\right]\left[\Delta\psi - \left(\tau_m - \tilde{\tau}_B\right)\right].$$

Since the second-order condition corresponding to (1) is that $\theta_i < 0$, equation (9) indicates that higher minimum taxes advance collective objectives whenever $\Delta\psi > \left(\tau_m - \tilde{\tau}_B\right)$.

3. Efficient Minimum Taxation.

A minimum tax rate that maximizes the value of $M\left(\tau_m\right)$ in (2) will have the property that the right side of (9) equals zero. If the weights that countries use to evaluate tax rates for competitive purposes are the same as the preference weights used to calculate $\tilde{\tau}_B$ and Δ,[2] then $\psi = 1$, and at an objective-maximizing minimum tax rate, denoted τ_m^*, $M'\left(\tau_m^*\right) = 0$ implies

(10) $$\tau_m^* = \tilde{\tau}_B + \Delta .$$

Equation (10) indicates that the objective-maximizing minimum tax rate is the sum of the average tax rate of constrained countries and the average effect of competition on the tax rates of all countries. Of course, the set of group *B* countries whose tax rates are constrained by the minimum tax rule is itself a function of the minimum tax rate; but to find τ_m^*, it is simply necessary to search for values of τ_m for which $\tau_m - \tilde{\tau}_B = \Delta$.

3.1. Interpreting the condition.

If every country were in group *B* and therefore bound by the minimum tax, then Equations (7) and (10) together imply that the efficient minimum tax rate equals the average value of τ_i^*, the objective-maximizing rate in the absence of international competition. In this scenario, minimum taxation entirely undoes the average effect of tax competition. In the more general case that the minimum tax binds only a subset of countries, the aggregate correction is smaller. Since Δ in equation (10) is an average for all countries, the efficient minimum tax requires group *B* countries to impose a tax that is greater or less than their average value of τ_i^* to the extent that they are less or more affected by tax competition than are group *A* countries.

The efficient minimum tax rate takes a simple form in (10), which can be recast as $\Delta = \tau_m^* - \tilde{\tau}_B$. The left side of this equation, Δ, is the average effect of tax competition on tax rates – which, as indicated by (8), also captures the marginal benefit to all countries of increasing

[2] This entails $\nu_i = \theta_i w_i \big/ \sum \theta_i w_i$.

the world average tax rate. The right side, $\left(\tau_m^* - \tilde{\tau}_B\right)$, is the cost of further distorting the tax rates of constrained countries. The Taylor approximation in (4) makes country *i*'s cost of additional deviations from τ_i equal to $-\theta_i\left(\tau_m^* - \tau_i\right)$, the average value of which among all group *B* countries is $\left(\tau_m^* - \tilde{\tau}_B\right)$. Consequently, (10) simply expresses an equality between the marginal benefits and marginal costs of raising the minimum tax rate.

3.2. Evaluating minimum tax outcomes.

The impact of a minimum tax on the weighted sum of national objectives can be obtained by integrating both sides of (9), which produces

$$M\left(\tau_m\right) - S = \int_0^{\tau_m} \left[-\sum\nolimits_B \theta_i w_i\right]\left[\Delta\psi - \left(\tau_m - \tilde{\tau}_B\right)\right] dz. \tag{11}$$

Equation (11) can be evaluated by separately integrating the three terms on the right side, using integration by parts in each case. Appendix *B* provides the calculations, which invoke two summary measures, the first of which is $\bar{\tau}_B \equiv \dfrac{\sum_B \tau_i v_i}{\sum_B v_i}$, the average tax rate of group *B* countries, weighted by v_i. While both $\tilde{\tau}_B$ and $\bar{\tau}_B$ are average tax rates of group *B* countries, $\tilde{\tau}_B$ uses $\theta_i w_i$ weights, based on national preferences and collective assessments, whereas $\bar{\tau}_B$ uses v_i weights, which correspond to the significance of each country in calculating the world average tax rate against which countries compare their own rates. The second summary measure is $\sigma_B^2 \equiv \dfrac{\sum_B \left(\tau_i - \tilde{\tau}_B\right)^2 \theta_i w_i}{\sum_B \theta_i w_i}$, the weighted variance of group *B* tax rates, calculated using preference weights $\theta_i w_i$. The calculations in Appendix *B* show that (11) implies that

$$M\left(\tau_m\right) - S = \frac{-1}{2}\left[\left(\Delta\psi + \left(\tilde{\tau}_B - \bar{\tau}_B\right)\right)^2 - \left(\tau_m - \left(\Delta\psi + \tilde{\tau}_B\right)\right)^2 - \left(\tilde{\tau}_B - \bar{\tau}_B\right)^2 - \sigma_B^2\right]\sum\nolimits_B \theta_i w_i. \tag{12}$$

Equation (12) indicates that the net effect of a minimum tax on the weighted sum of country objectives depends in part on the extent to which the minimum tax binds on countries

$\left(\sum_B \theta_i w_i\right)$, any differences between $\tilde{\tau}_B$ and $\overline{\tau}_B$, and differences between the tax rates that affected countries would choose independently $\left(\sigma_B^2\right)$. The variance term reflects that minimum taxation does more than raise the average tax rates of affected countries: minimum taxation also harmonizes these rates, which is costly to those who would otherwise choose tax rates that differ from the group mean.

3.3. Dominated minimum tax rate regions.

Equation (9) implies that, if tax competition reduces average tax rates, so $\Delta > 0$, then a low rate of minimum taxation enhances collective objective attainment compared to a regime with no minimum taxes. At a very low minimum tax rate, $\left(\tau_m - \tilde{\tau}_B\right)$ is close to zero, but Δ will not be, so the right side of (9) is positive, and therefore $M'\left(\tau_m\right) > 0$. Consequently, there are many cases in which positive minimum taxes advance collective objectives – though there remains the question of which minimum tax rates do so efficiently.

One of the important implications of (10) is that multiple solutions are possible, depending on the distribution of country tax rates. As noted earlier, this multiplicity arises because a minimum tax bears only on the lowest-tax countries, so the only way to raise the tax rates of additional countries is by imposing a higher minimum. Mechanically, $M'\left(\tau_m\right)$ may change signs multiple times: $M'\left(\tau_m\right)$ starts positive, is zero at the first local maximum, and is negative immediately thereafter; but it is possible for $M'\left(\tau_m\right)$ to become positive again at a higher minimum tax rate, if $\left(\tau_m - \tilde{\tau}_B\right)$ declines sufficiently. This happens if the average tax rate of group *B* countries increases more than one for one with τ_m over certain tax ranges, as will be the case if the distribution of national tax rates is concentrated at points such as 15% and 25%.[3] Notably, this arises even though the Taylor approximations remove some potential sources of $M'\left(\tau_m\right)$ sign reversal by ruling out higher-order preference terms; but the weighted objective

[3] It is not necessary that $\tilde{\tau}_B$ change discontinuously in order for $M'\left(\tau_m\right)$ to transition from negative to positive as τ_m increases, only that tax rate density in certain neighborhoods is sufficiently high; Appendix *C* presents sufficient conditions.

function may nonetheless have multiple solutions due to the unrestricted distribution of preference parameters and preferred tax rates τ_i^*.

If $M'(\tau_m)$ changes sign from negative to positive, then more than one τ_m may satisfy (10) for a given value of Δ, in which case it is necessary to use (12) to evaluate which τ_m most effectively advances collective objectives. This can make the mapping from Δ to τ_m^* discontinuous, featuring dominated ranges of minimum tax rates that do not maximize collective objectives at any level of Δ.

3.4. Application to a bimodal tax distribution.

A simple example illustrates the potential for dominated tax regions. Suppose that there are 200 countries in the world, all of equal size, and with identical values of θ_i, v_i, and w_i; only their τ_i^* and $\frac{\partial O_i}{\partial d_i}$ preferences differ, as a result of which, in the absence of a minimum tax, 100 countries choose a tax rate of 5%, while 100 choose 25%. A minimum tax below 25% would bear on the 100 countries that would otherwise chose tax rates of 5%, so (10) implies that, if the efficient minimum tax lies in this range, then $\tau_m^* = 0.05 + \Delta$. Alternatively, a minimum tax above 25% would bear on all 200 countries, in which case (10) implies that $\tau_m^* = 0.15 + \Delta$. Consequently, there are two scenarios, one in which the efficient minimum tax rate is less than 25% and equal to $0.05 + \Delta$; and the other in which it is greater than 25% and equal to $0.15 + \Delta$. The first case requires $\Delta < 0.20$, and the second requires $\Delta \geq 0.10$; if Δ lies between 0.10 and 0.20, both of these rules would produce locally efficient minimum tax rates, but they differ, and only one maximizes the weighted sum of country objectives.

Equation (12) assists in selecting between these two minimum tax rate possibilities, since an efficient choice τ_m^* maximizes $M\left(\tau_m^*\right) - S$, conditional on Δ. The parameter assumptions imply that $\tilde{\tau}_B = \overline{\tau}_B$, and if the minimum tax rate is less than 25%, the affected countries all have the same tax rate, so $\sigma_B^2 = 0$ and $\frac{\sum_B \theta_i w_i}{\sum \theta_i w_i} = \frac{1}{2}$. Therefore it follows from (12) that

$M\left(\tau_m^*\right) - S = \frac{-\Delta^2}{4}\sum \theta_i w_i$. Alternatively, if the minimum tax rate is greater than 25%, then $\tilde{\tau}_B = 0.15$, and all of the affected countries' tax rates differ from the mean by 0.10, making $\sigma_B^2 = 0.01$, and $M\left(\tau_m^*\right) - S = \frac{-1}{2}\left(\Delta^2 - 0.01\right)\sum \theta_i w_i$. The $M\left(\tau_m^*\right) - S$ values associated with the two scenarios are equal if $\frac{\Delta^2}{4} = \frac{1}{2}\left(\Delta^2 - 0.01\right)$, which corresponds to $\Delta = 0.1414$. The efficient minimum tax rate is therefore $0.05 + \Delta$ if $\Delta < 0.1414$; and it is $0.15 + \Delta$ if $\Delta \geq 0.1414$.

Figure 1 depicts the implied efficient minimum tax rate as a function of Δ. It is evident from the figure that 19.14% - 29.14% is a dominated tax rate range, in that there is no value of Δ for which a minimum tax between 19.14% and 29.14% would represent an efficient choice. This arises due to the heavy concentration of tax rates at 25%. As a result, $\left(\tau_m - \tilde{\tau}_B\right)$ declines sharply at $\tau_m = 0.25$, increasing $M'\left(\tau_m\right)$, and making minimum taxes in the neighborhood of 25% particularly inefficient.

3.5. Minimum taxes in a coalition.

The analysis to this point considers the effect of a worldwide minimum tax. There may be circumstances in which a coalition of countries, such as those in a trade bloc, contemplates requiring the tax rates of its members to equal or exceed a specified minimum. Properly interpreted, the prior analysis applies to members of the coalition seeking to maximize their collective objectives. In this case, $\tilde{\tau}_B$ would be the average tax rates of coalition countries constrained by the minimum tax, τ_i^* the tax rate that coalition member *i* would choose if it knew that every other country in the coalition would have the same rate, and Δ the effect of tax competition in reducing coalition tax rates below τ_i^*. Since this minimum tax would not constrain the tax rates of countries outside the coalition, a member's τ_i^* is likely to be significantly lower than the τ_i^* it would choose if it knew that all other countries would have the same rate. This produces a smaller implied Δ – in the limiting case that a coalition consists of a single country, its Δ is zero – and a resulting lower value of τ_m^*.

4. *Application to World Tax Rates.*

It is evident from (10) that minimum tax rates that maximize collective objectives are functions both of Δ and of the distribution of observed tax rates. Consequently, it is necessary to use data to evaluate the extent to which different minimum tax rates may be consistent with maximizing collective objectives. In order to do so, however, it is necessary to specify the $\theta_i w_i \Big/ \sum \theta_i w_i$ weights, an exercise complicated by the reality that these weights are unknown. If collective decision makers attach equal weight to costs imposed on different countries, either because they anticipate making transfers to offset distributional consequences, or for other reasons, then w_i is the same for all, and the remaining $\theta_i \Big/ \sum \theta_i$ weights capture relative willingness to pay to avoid disfavored tax rates. If willingness to pay is proportional to income and therefore GDP, then the first term on the right side of (10) is the average tax rate of affected countries calculated using GDP weights. Using GDP weights to proxy for $\theta_i \Big/ \sum \theta_i$ relies on the assumption that countries with similar incomes find it equally costly to deviate from their preferred tax rates. While this is entirely plausible, it need not be the case, since economic and political conditions differ, as a result of which some countries may feel more strongly than others about taxing at their preferred rates. In the absence of detailed information on country preferences, GDP weights are reasonable choices, capturing the effects of economic scale on the consequences of taxes and therefore the amounts that countries are likely willing to pay.

4.1. *Features of minimum taxation in 2020.*

Figure 2 uses GDP weights to plot 2020 values of $\tilde{\tau}_B$ for statutory corporate income tax rates of the 177 countries for which tax rate and GDP data are available.[4] As might be expected, the locus in Figure 2 exhibits sharp upward jumps at popular tax rates such as 15%, 20%, and 25%. Figure 3 is the corresponding plot of $\left(\tau_m - \tilde{\tau}_B\right)$, again using GDP weights. It is clear from

[4] Tax rate data are reported by the Tax Foundation at https://taxfoundation.org/publications/corporate-tax-rates-around-the-world/. The analysis uses 2020 data for 178 countries, but the single country (Comoros) with the highest tax rate is outside the range of the figures, and so not depicted. Hines (2023) reports tax rate weighted means and standard deviations for the tax types, years, and weighting schemes used to construct the diagrams presented here.

the sawtooth pattern in Figure 3, and resulting multiplicity of minimum tax rates τ_m supporting common values of $\left(\tau_m - \tilde{\tau}_B\right)$, that there will be multiple local objective-maximizing points for many values of Δ between 2% and 8%. For example, minimum tax rates of 5%, 23.7%, 28.8, and 30.3% all satisfy (10) for $\Delta = 5$. Applying (12) to identify which of the locally efficient points at each value of Δ maximizes collective objective satisfaction, and omitting those that do not, yields Figure 4, depicting the implied objective-maximizing τ_m^* as a function of Δ.

Figure 4 indicates that the objective-maximizing choice τ_m^* increases one-for-one with Δ over the range 0-3.8%. There is then a discontinuous jump in the objective-maximizing τ_m: at $\Delta = 3.87$, collective objectives are maximized by $\tau_m = 3.87$, whereas at $\Delta = 3.88$, collective objectives are maximized by $\tau_m = 27.4$. There is no value of Δ for which a minimum tax rate between 3.8% and 27.4% would maximize collective objectives. And as Figure 4 also indicates, there is a subsequent noticeable, though smaller, discontinuous jump in the objective-maximizing τ_m in the neighborhood of 30%.

4.2. Minimum taxes in earlier years and with alternative weighting schemes.

The evidence presented in Figures 3 and 4 uses statutory corporate tax rates weighted by GDP, which corresponds to collective decisions based on willingness to pay. An alternative possibility is that collective decisions might weight outcomes by population. Since GDP is the product of population and per-capita GDP, decision makers might use population weights if their criterion were the product of willingness to pay (measured by GDP) and the marginal value of resources (proxied by the inverse of per capita GDP). In the data for 2020, the use of population weights for outcomes, while retaining GDP weights for tax comparisons, produces the familiar sawtooth pattern of $\left(\tau_m - \tilde{\tau}_B\right)$ at different values of τ_m, and a resulting mapping from Δ to τ_m^* that exhibits sharp jumps and therefore wide dominated ranges of minimum tax rates. Appendix D.1 displays figures corresponding to these calculations, which look quite similar to those for GDP weights presented in Figures 3 and 4.

The 2020 patterns are not products of conditions unique to that year. Appendix D.2 presents figures corresponding to Figures 3 and 4 for the years 2000 and 2010, using both GDP and population weights for country objectives. In all of these cases $\left(\tau_m - \tilde{\tau}_B\right)$ is a jagged function of τ_m, making the implied values of τ_m^* discontinuous functions of Δ.

The calculations that are the basis of Figures 3-4, and those used to produce the figures in Appendices D.1 and D.2, construct ψ using GDP weights for v_i. The use of GDP weights for v_i corresponds naturally to settings in which governments entertain minimum taxes as methods of addressing concerns arising from tax competition. While the imposition of minimum taxes also affects opportunities for tax avoidance, the fundamental function of minimum taxation lies in its impact on competition. Countries could, if they wish, adopt strong unilateral measures to protect their tax bases,[5] including those contained in the OECD (2021) blueprint – but those otherwise inclined are deterred from doing so on a unilateral basis out of concern for their economic and anticompetitive effects, reactions from other countries, and the domestic politics of deviating from world norms. Since in most competitive settings a country's impact is proportional to its economic size, GDP is a natural weighting variable for v_i. It is nonetheless informative to consider other possibilities. Appendix D.3 presents the outcomes of calculating ψ using 2020 population weights for v_i, with patterns that differ very little from those in Figure 4 and Appendix Figure D.1.b.

Population weights are not the only v_i alternatives to GDP. If countries are particularly concerned about profit shifting, then in constructing $\overline{\tau}$ they might attach disproportionately high weights to tax rates available in tax haven countries. Appendix D.4 considers a setting in which countries care only about the difference between their tax rates and the average rate available in tax haven countries; Appendix Figure D.4 presents the resulting efficient tax rates, which again exhibit discontinuous jumps and accompanying dominated regions. Appendix D.4 also shows that, in the more extreme case that countries care only about the differences between their own tax rates and those in zero-tax-rate havens, the resulting efficient minimum tax rates do not display discontinuous jumps. The reason why they do not is that, in this scenario, there are no competitive benefits of bringing minimum taxes to bear on additional countries.

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[5] As argued, for example, by Dharmapala (2021).

4.3. *Minimum effective tax rates.*

While the statutory corporate tax rate is a very important component of the effective corporate tax burden, rules concerning income inclusions, the availability of tax credits and deductions, and other aspects of tax base definitions also play important roles.[6] Consequently, an analysis of statutory corporate tax rates can offer an incomplete picture of relative tax burdens. It is useful to consider the extent to which dominated ranges of the type evident in Figure 4 persist with tax rates defined in a manner that adjusts for tax base differences. Devereux and Griffith (2003) propose a method of calculating effective average corporate tax rates relevant to location choices by multinational firms. This effective corporate tax rate measure is sensitive to tax base definitions, and serves as the foundation of the calculations by Spengel et al. (2021) of effective corporate tax burdens in European and other high-income countries. The limited coverage of the Spengel et al. data, consisting of 35 countries in 2020 and 2010, and 28 countries in 2000, means that applying the framework of sections 2 and 3 to these samples corresponds to evaluating minimum taxation in coalitions of countries rather than the world as a whole. Since a minimum tax adopted by a coalition applies only to a portion of the world, the resulting efficient (from the standpoint of the coalition) minimum tax rate is likely to be significantly lower than would be the case a global minimum tax. It is nonetheless valuable to investigate the extent to which efficient minimum tax rates may exhibit dominated ranges, understanding that these minimum rates, and the values of Δ to which they correspond, are apt to be lower than would be the case if the coalition were the whole world.

Figure 5 presents efficient minimum tax rates calculated using 2020 effective tax rate data for the 35-country coalition. Efficient minimum effective tax rates among the coalition members exhibit discontinuous jumps in Δ. The figure indicates that the objective-maximizing choice τ_m^* increases discontinuously from 10.1% to 14.6% at $\Delta = 1.29$, from 17.9% to 21.3% at $\Delta = 3.55$, and from 25.1% to 29.8% at $\Delta = 4.91$. Appendix D.5 presents other figures corresponding to Figure 3, and the figures presented in Appendices D.1 and D.2, all using effective tax rate data for the 35- and 28-country coalitions. Sharper discontinuous jumps appear in the τ_m^* schedules for 2010 (Appendix Figure D.5.c) and 2000 (Appendix Figure D.5.e); and the τ_m^* schedule also features marked discontinuous jumps when countries weight outcomes by population (Appendix Figure D.5.g).

The efficient minimum tax effective tax rate schedule depicted in Figure 5 differs from its statutory tax counterpart in Figure 4 both because effective and statutory tax rates differ, and because the exercise of imposing a minimum tax on a select group of 35 higher-income countries differs from that of imposing a minimum tax among 178 countries. Figure 6 presents efficient statutory minimum tax rates for the 35-country coalition considered in Figure 5. The figure indicates that, for 2020, efficient minimum statutory tax rates exhibit discontinuous jumps similar to those of efficient minimum effective tax rates: τ_m^* increases discontinuously from 11.4% to 13.4% at $\Delta = 2.11$; from 14.1% to 20.7% at $\Delta = 2.83$, and again from 22.8% to 27.4% at $\Delta = 3.33$, along with other smaller jumps. Sharp discontinuous jumps also appear in efficient minimum statutory tax rate schedules for 2010 (Appendix Figure D.5.h) and 2000 (Appendix Figure D.5.i). In all of these cases, efficient minimum statutory tax rates at low levels of Δ significantly exceed the corresponding efficient minimum statutory rates in Figure 4, Appendix Figure D.2.b, and Appendix Figure D.2.d, reflecting the high tax rates of the 35-country and 28-country coalition members and that Δ depends on the size and composition of a coalition.

Efficient minimum tax rates exhibit discontinuous jumps in all time periods, country groupings, and tax types. While specific minimum tax schedules differ, they share common features, and reflect the same forces, which produce dominated regions in the neighborhood of popular tax rates such as 15% and 20%.

5. Minimum Taxes and Collective Objectives.

Equation (12) can be used to evaluate the extent to which a minimum tax advances collective objectives – though any evaluation necessarily involves a comparison with a specified alternative, since the $M\left(\tau_m\right)$ function does not have an interpretable scaling. One potential alternative is to forego a minimum tax and instead address the effects of tax competition by

[6] Furthermore, in practice, statutory corporate tax rate changes tend to be accompanied by corporate tax base

increasing every country's tax rate by the same amount. Since this alternative entails increasing every tax rate in lockstep, it would not affect any d_i. Expressing the common tax increase as $\alpha\Delta$, a fraction α of the average effect of tax competition Δ, the fundamental theorem of the calculus together with equation (6) implies

$$O_i\left(\tau_i+\alpha\Delta,d_i\right)-O_i\left(\tau_i,d_i\right)=\int_{\tau_i}^{\tau_i+\alpha\Delta}\frac{\partial O_i\left(\tau_i,d_i\right)}{\partial\tau_i}d\tau_i=-\int_{\tau_i}^{\tau_i+\alpha\Delta}\theta_i\left(\tau_i^*-\tau_i\right)d\tau_i\,. \tag{13}$$

Evaluating the integral on the right side of (13),

$$-\int_{\tau_i}^{\tau_i+\alpha\Delta}\theta_i\left(\tau_i^*-\tau_i\right)d\tau_i=-\theta_i\tau_i^*\alpha\Delta+\theta_i\left(\alpha\Delta\tau_i+\frac{1}{2}\alpha^2\Delta^2\right)=-\theta_i\left(\tau_i^*-\tau_i\right)\alpha\Delta+\frac{1}{2}\theta_i\alpha^2\Delta^2\,. \tag{14}$$

Equations (13) and (14), together with the definition of Δ in (7), imply that

$$\sum\left[O_i\left(\tau_i+\alpha\Delta,d_i\right)-O_i\left(\tau_i,d_i\right)\right]w_i=\frac{1}{2}\left(\alpha^2-2\alpha\right)\Delta^2\sum\theta_i w_i\,. \tag{15}$$

The value of α on the right side of equation (15) serves as a measure of the impact of a minimum tax on the weighted sum of national objectives.[7] Setting the left side of (15) equal to $M\left(\tau_m\right)-S$, and using the quadratic formula to solve for α, yields

$$\alpha=1-\sqrt{1+\frac{2\left[M\left(\tau_m\right)-S\right]}{\Delta^2\sum\theta_i w_i}}\,. \tag{16}$$

Consequently, the effect of any minimum tax can be evaluated by using equation (12) to solve for $M\left(\tau_m\right)-S$, then applying (16) to obtain α.

Figure 7 presents values of α corresponding to efficiently-chosen minimum tax rates for different levels of Δ, using GDP weights for cases in which $\psi=1$ and $\tilde{\tau}_B=\overline{\tau}_B$.[8] As is clear

changes (Kawano and Slemrod, 2016).

[7] Notably, the right side of (15) is maximized by $\alpha=1$, corresponding to all tax rates increasing by Δ, and thereby entirely undoing the effect of competition on average tax rates.

from the figure, at low levels of Δ efficient minimum taxes achieve outcomes comparable to those produced by undoing just very small fractions of the effect of tax competition. This reflects that corresponding efficient minimum tax rates are very low, and therefore bear on small fractions of the world economy. Even when $\Delta = 4.2$, the corresponding efficient minimum tax rate of 28% achieves an outcome comparable to undoing just 6% of the effect of tax competition. At $\Delta = 6.2$, the 31.5% efficient minimum tax rate produces an outcome comparable to undoing 30% of the effect of tax competition, and this fraction characterizing the effect of efficient minimum taxation continues to rise as Δ increases, ultimately asymptoting to one.

There is particular interest in a minimum tax rate of 15%, given the OECD (2021) proposal to introduce a world minimum tax at that rate. Figure 8 presents implied values of α for a 15% minimum statutory corporate tax. The locus in Figure 8 indicates that $\alpha < 0$ if $\Delta < 5.69$, so the tax would impede the attainment of collective objectives unless tax competition reduces average rates by at least 5.69%. If $\Delta > 5.69$ then a minimum tax rate of 15% advances collective objectives, though the corresponding value of α is never as high as one percent. The consistently low values of α stem more from the inefficiency of a 15% rate than they do from the inability of a minimum tax to achieve objectives, since the α associated with a minimum tax rate of 15% is everywhere less than two percent of the α associated with an efficient minimum tax rate τ_m^*.

Figure 9 presents implied values of α for minimum tax rates of 15%, 21%, and 28%, with α values for efficient minimum taxes superimposed for comparison. The figure indicates that, as in the case of a 15% minimum tax, the α associated with a 21% minimum tax everywhere takes small values, lying consistently below 3%. By contrast, the α values associated with a minimum tax of 28% are quite a bit larger, peaking at 22% for $\Delta = 7.65$. It is evident from Figure 9 that, at every value of Δ for which a minimum tax of 15% contributes positively to the weighted sum of national objectives, a minimum tax of 28% contributes quite a bit more. Furthermore, a 28% minimum tax contributes positively to weighted national objectives over a broader range than does a 15% minimum tax, doing so starting at $\Delta = 3.83$. It

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[8] With these assumptions, (12) and (16) together imply that $\alpha = 1 - \sqrt{1 - \left[1 - \frac{\sigma_B^2}{\Delta^2}\right] \frac{\sum_B \theta_i w_i}{\sum \theta_i w_i}}$.

is only over very low values of Δ, at which neither a 15% nor a 28% minimum tax advances collective objectives, that a 15% minimum tax is associated with a higher (negative) value of α.

A 15% minimum effective tax rate adopted by the 35-country coalition similarly produces very little in the way of collective objective satisfaction. Figure 10 presents implied values of α for minimum effective tax rates of 15%, 21%, and 28%, along with efficient minimum taxes, all for the 35-country coalition. The α associated with a 15% minimum tax takes very low values, peaking at 1.3% (for $\Delta = 2.4$). At higher levels of Δ, a minimum effective tax rate of 21% produces somewhat greater values of α, peaking at 4.9% for $\Delta = 5.8$; and a minimum tax rate of 28% again offers a significantly higher top value of α, peaking at 13.7% for $\Delta = 9.1$.[9] Figure 10 indicates that there exists a range of coalition Δ over which a 15% minimum effective tax produces a positive (albeit small) value of α and the 21% and 28% minimum effective taxes do not; and Appendix Figure D.6 shows that the same is true for minimum statutory tax rates for the 35-country coalition.

6. *Minimum Taxes with Strategic Interactions.*

This section considers the impact of minimum taxation in settings with strategic tax interactions. For this purpose, it is extremely helpful to consider situations in which all countries exhibit the same reaction to external tax rates, so $\frac{d\tau_i}{d\overline{\tau}}$ is the same for everyone.[10] Imposing that $\frac{\partial^2 O_i}{\partial d_i^2} = \gamma\theta_i$ and $\frac{\partial^2 O_i}{\partial \tau_i \partial d_i} = \lambda\theta_i$, with γ and λ the same for all countries, then, as noted in Appendix *A*, $\frac{d\tau_i}{d\overline{\tau}} = \frac{\gamma+\lambda}{1+2\lambda+\gamma}$. As a result, $\hat{\tau}_i = \tau_i + k$, in which $k = \left[\frac{\gamma+\lambda}{1+2\lambda+\gamma}\right]\left(\overline{\tau}_m - \overline{\tau}\right)$ is the amount by which all countries would choose to increase their tax rates in response to higher world tax rates brought about by the minimum tax. While every country would prefer to

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[9] These values of α are not directly comparable to those in Figures 7-9, as Δ and α take different meanings when applied only to coalitions.

[10] With unrestricted reaction functions $\partial\tau_i / \partial\overline{\tau}$, it would be impossible to use observed tax rates to infer which countries would ultimately fall into groups *A* and *B*, since even a very low tax rate country might respond to $\overline{\tau}_m > \overline{\tau}$ by so increasing its tax rate that it would fall into group *A*.

increase its tax rate by *k*, the minimum tax requires countries in group *B* to increase their taxes even more. Applying first-order approximations, it follows that, for group *B* countries,

$$\frac{\partial O_i\left(\tau_m,\tau_m-\overline{\tau}_m\right)}{\partial \tau_i}=\frac{\partial O_i\left(\tau_i+k,\tau_i+k-\overline{\tau}_m\right)}{\partial \tau_i}+\theta_i\left(\tau_m-\tau_i-k\right)+\lambda\theta_i\left[\left(\tau_m-\overline{\tau}_m\right)-\left(\tau_i+k-\overline{\tau}_m\right)\right] \tag{17}$$

$$\frac{\partial O_i\left(\tau_m,\tau_m-\overline{\tau}_m\right)}{\partial d_i}=\frac{\partial O_i\left(\tau_i+k,\tau_i+k-\overline{\tau}_m\right)}{\partial d_i}+\lambda\theta_i\left(\tau_m-\tau_i-k\right)+\gamma\theta_i\left[\left(\tau_m-\overline{\tau}_m\right)-\left(\tau_i+k-\overline{\tau}_m\right)\right]. \tag{18}$$

Summing (17) and (18), and applying (1),

$$\sum\nolimits_B\left(\frac{\partial O_i\left(\tau_m,\tau_m-\overline{\tau}_m\right)}{\partial \tau_i}+\frac{\partial O_i\left(\tau_m,\tau_m-\overline{\tau}_m\right)}{\partial d_i}\right)w_i=\left(1+2\lambda+\gamma\right)\left(\tau_m-\tilde{\tau}_B-k\right)\sum\nolimits_B\theta_i w_i\,, \tag{19}$$

the left side of which is the same as the second term on the right side of equation (3).

In order to evaluate the first term on the right side of equation (3), it is helpful to start by considering the value of $\frac{\partial O_i\left(\hat{\tau}_i,\hat{\tau}_i-\overline{\tau}_m\right)}{\partial \tau_i}$, based on a first-order approximation starting at $\left(\tau_i^*,0\right)$:

$$\frac{\partial O_i\left(\hat{\tau}_i,\hat{\tau}_i-\overline{\tau}_m\right)}{\partial \tau_i}=\frac{\partial O_i\left(\tau_i^*,0\right)}{\partial \tau_i}+\theta_i\left(\tau_i+k-\tau_i^*\right)+\lambda\theta_i\left(\tau_i+k-\overline{\tau}_m\right). \tag{20}$$

Since τ_i^* is an optimizing choice, $\frac{\partial O_i\left(\tau_i^*,0\right)}{\partial \tau_i}=0$; and since equation (1) implies that, for group *A* countries who are not constrained by the minimum tax, $\frac{\partial O_i\left(\hat{\tau}_i,\hat{\tau}_i-\overline{\tau}_m\right)}{\partial d_i}=-\frac{\partial O_i\left(\hat{\tau}_i,\hat{\tau}_i-\overline{\tau}_m\right)}{\partial \tau_i}$, it follows from (20) that, for group *A* countries,

$$\frac{\partial O_i\left(\hat{\tau}_i,\hat{\tau}_i-\overline{\tau}_m\right)}{\partial d_i}=\theta_i\left(\tau_i^*-\tau_i-k\right)+\lambda\theta_i\left(\overline{\tau}_m-\tau_i-k\right). \tag{21}$$

Group B countries are constrained by the minimum tax, so equation (21) does not characterize their values of $\frac{\partial O_i\left(\tau_m, \tau_m - \overline{\tau}_m\right)}{\partial d_i}$; but (18) does, with $\frac{\partial O_i\left(\tau_i + k, \tau_i + k - \overline{\tau}_m\right)}{\partial d_i}$ given by (21).

6.1. Efficient minimum taxation with strategic interactions.

Equations (18)-(21) can be applied to equation (3) to solve for efficient minimum taxes when tax rates exhibit strategic reactions. Appendix *E* presents the somewhat laborious calculations, which yield

$$\tau_m^* - k = \tilde{\tau}_B + \frac{\Delta\psi - \lambda\left(\tilde{\tau} - \overline{\tau}\right)\psi - \left(\tilde{\tau}_B - \overline{\tau}_B\right)\frac{\sum_B \theta_i w_i}{\sum \theta_i w_i}\psi^2\left(\frac{(\lambda+\gamma)}{(1+\lambda)} - \lambda\right)}{1 + \frac{(\lambda+\gamma)}{(1+\lambda)}\frac{\sum_B \theta_i w_i}{\sum \theta_i w_i}\psi^2 + \lambda\left(1 - \frac{\sum_B \theta_i w_i}{\sum \theta_i w_i}\psi^2\right)}, \tag{22}$$

in which $\tilde{\tau} \equiv \frac{\sum \tau_i \theta_i w_i}{\sum \theta_i w_i}$ is the average tax rate of all countries, weighted by $\theta_i w_i$. A minimum tax raises the world average tax rate to $\overline{\tau}_m$, which induces every country to increase its tax rate by the amount *k*. It follows that the left side of equation (22), $\left(\tau_m^* - k\right)$, is the current tax rate of a country for which an efficient minimum tax, if implemented, would just start to bind. Values of $\left(\tau_m^* - k\right)$ can be identified by finding points in the data for which (22) is satisfied. The value of $\left(\tau_m^* - k\right)$ implied by equation (22) differs from the value of τ_m^* implied by equation (10), one notable difference being that the denominator of the second term on the right side of (22) is one plus a weighted average of $\frac{(\lambda+\gamma)}{(1+\lambda)}$ and λ. Positive values of λ and γ, which make tax rates strategic complements, dampen the effect of Δ on $\left(\tau_m^* - k\right)$; the opposite happens if λ and γ are negative, in which case tax rates are strategic substitutes.

When multiple values of τ_m^* satisfy (22) for the same Δ, it is necessary to look beyond (22) to identify which choice maximizes collective objectives. Appendix F provides equation

(F12), which generalizes (12) to settings in which tax rates exhibit strategic reactions, and can be used to compare minimum taxes satisfying (22).

Equation (22) can be solved for the implied value of τ_m^*. As derived in Appendix *E* for the special case that $\psi = 1$, $\bar{\tau} = \tilde{\tau}$ and $\tilde{\tau}_B = \bar{\tau}_B$, the efficient minimum tax rate is given by

$$\tau_m^* = \tilde{\tau}_B + \Delta\left[1 - \frac{\lambda\left(1 - \frac{\sum_B \theta_i w_i}{\sum \theta_i w_i}\right)}{1 + \frac{(\lambda+\gamma)}{(1+\lambda)}\frac{\sum_B \theta_i w_i}{\sum \theta_i w_i} + \lambda\left(1 - \frac{\sum_B \theta_i w_i}{\sum \theta_i w_i}\right)}\right]. \tag{23}$$

Equation (23) differs from (10) in two respects. The first is that the group *B* countries whose average tax rate is the first term on the right side of (23) are not those with tax rates below τ_m^*, but instead those with tax rates below $\left(\tau_m^* - k\right)$. The second is that the right side of (23) includes an adjustment to Δ. This adjustment is apt to be small, since the λ term that appears in (23) reflects the effect of deviations of a country's tax rate from the world average on its valuation of further deviating from its desired tax rate. As λ diminishes in magnitude, and as the minimum tax rate rises, increasing $\frac{\sum_B \theta_i w_i}{\sum \theta_i w_i}$, (23) more closely approximates $\tau_m^* = \tilde{\tau}_B + \Delta$.

6.2. Implied efficient tax rates.

Incorporating strategic interactions appears to affect the levels but not the patterns of efficient tax rates. Applying (23), Figures 11 and 12 present plots of efficient minimum tax rates for two scenarios with strategic complementarity: $\gamma = 0.4$ and $\lambda = 0.05$, which implies that $d\tau_i / d\bar{\tau} = 0.3$; and $\gamma = 1$ and $\lambda = 0.1$, which implies that $d\tau_i / d\bar{\tau} = 0.5$. These τ_m^* schedules feature discontinuous jumps, and do so with roughly the same patterns as in Figure 4, though the jumps appear at higher levels of Δ. For example, in Figure 11, describing efficient minimum tax rates with $d\tau_i / d\bar{\tau} = 0.3$, the large discontinuous jump in τ_m occurs at $\Delta = 4.45$, at which point the efficient minimum tax rate increases from 4.2% to 28.2%.

It is noteworthy that even rather pronounced degrees of strategic complementarity, those responsible for $d\tau_i/d\bar{\tau} = 0.3$ or $d\tau_i/d\bar{\tau} = 0.5$, have only modest impacts on efficient tax rate patterns. Figure 13 repeats Figure 3, in which $\Delta = 5$, superimposing two additional schedules that incorporate the second term on the right side of (23), the adjustment to Δ for strategic behavior. The adjustments for strategic behavior depicted in Figure 13 are relatively minor. In the absence of strategic behavior, the efficient minimum tax rate is 30.3%; whereas in the scenario with $d\tau_i/d\bar{\tau} = 0.3$, the efficient minimum tax rate is 28.6%. The modest rightward ratchet in the Δ locus induced by strategic behavior does not alter the fundamental pattern that dense population concentrations create dominated tax rate regions. The scenario with $d\tau_i/d\bar{\tau} = 0.5$ has an efficient minimum tax rate schedule similar to that for $d\tau_i/d\bar{\tau} = 0.3$, though $\Delta = 5$ lies just prior to its large discontinuous jump, making the corresponding efficient minimum tax rate 4.5%.

Appendix Figures D.7.a and D.7.b repeat the exercises of Figures 11 and 12, this time for effective rather than statutory tax rates, and applied to a coalition of countries. The efficient minimum tax rate schedules again exhibit discontinuous jumps that reflect dominated tax rate regions. In Figure D.7.a, depicting efficient minimum effective tax rates when $d\tau_i/d\bar{\tau} = 0.3$, there is a discontinuous jump in τ_m at $\Delta = 3.49$, at which point the efficient minimum tax rate increases from 14.7% to 27.2%; and there are smaller prior and subsequent dominated tax rate ranges. Figure D.7.b, depicting efficient minimum effective tax rates when $d\tau_i/d\bar{\tau} = 0.5$, features similar jumps. These dominated regions appear at higher values of Δ than in the corresponding Figure 5 depicting efficient minimum taxes in the absence of strategic interactions, but are otherwise quite similar.

7. Tax Competition and Minimum Taxation.

Countries seek minimum tax agreements in efforts to reverse the effects of tax competition on tax rates. In theory, a competitive global environment might lead to tax rates that are higher or lower than the rates countries would choose in autarky: eagerness to have tax rates that are competitive with others puts downward pressure on rates,[11] whereas the possibility of tax exporting exerts upward pressure.[12] As a result, independently set tax rates may be inefficiently high or inefficiently low from the standpoint of collective objectives. The direction of strategic reaction is likewise uncertain: in some settings tax rates will be strategic complements;[13] in others they are strategic substitutes;[14] and they might well be neither. While there are common intuitions that competitive forces depress tax rates, that rates are more likely to be strategic complements than strategic substitutes, and that minimum taxes therefore have the potential to push back against the effects of competition,[15] the absence of clear theoretical predictions means that evidence is needed in order to apply the theory.

World statutory and effective corporate tax rates have declined significantly in recent decades,[16] which suggests, though does not prove, that intensifying tax competition is responsible for this trend. Additional evidence is available in the cross section: smaller countries generally have lower tax rates,[17] which is one of the implications of tax competition models.[18] In some settings, tax rates appear to be strategic complements,[19] though this is by no means a universal tendency, as there are also reaction function estimates implying that tax rates are strategic substitutes;[20] and in some settings tax rates appear to be neither.[21] Consequently, while

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[11] See, for example, Zodrow and Mieszkowski (1986), Wilson (1986), Wildasin (1988), Black and Hoyt (1989), Bucovetsky and Wilson (1991), Bucovetsky (1991), and Baldwin and Krugman (2004); Davies and Eckel (2010), Haufler and Stähler (2013) and Niu (2017) consider the implications of taxpayer heterogeneity for the tax-setting game.

[12] See for example Haufler and Wooton (1999), Keen and Kotsogiannis (2002, 2004), Noiset (2003), Madiès (2008), and Keen and Konrad (2013).

[13] See, for example, Rota-Graziosi (2019) and the studies surveyed in Wilson (1999) and Keen and Konrad (2013).

[14] See Mintz and Tulkens (1986), Zodrow and Mieszkowski (1986), Wildasin (1988), Mendoza and Tesar (2005), and Vrijburg and de Mooij (2016).

[15] Konrad (2009) and Kiss (2012) consider the intriguing possibility that minimum tax agreements might actually reduce equilibrium tax rates by changing reaction functions or limiting the ability of countries to punish others for deviating from collusive agreements to maintain high tax rates. Peralta and van Ypersele (2006), Johannesen (2022), Hebous and Keen (2023), Janeba and Schjelderup (2023), and Haufler and Kato (2024) consider settings in which the introduction of a minimum tax, or a minimum tax coupled with a maximum tax, will advance the objectives of all countries. Devereux (2023), Faulhaber (2023), and Hanlon and Nessa (2023) analyze aspects of the OECD minimum tax proposal.

[16] This is documented by Slemrod (2004), Hines (2007), Ali Abbas and Klemm (2013), Keen and Konrad (2013), Azémar, Desbordes, and Wooton (2020), and Hines (2023).

[17] See Hines and Rice (1994), Bretschger and Hettich (2002), Hines (2007), and Dharamapala and Hines (2009).

[18] See Bucovetsky (1991), Wilson (1991), and Haufler and Wooton (1999).

[19] See Hayashi and Boadway (2001), Devereux, Lockwood and Redoano (2008), Overesch and Rincke (2011), Altshuler and Goodspeed (2015), and Merlo et al. (2023); Leibrecht and Hochgatterer (2012) and Devereux and Loretz (2013) survey this literature.

[20] See, for example, the analysis in Rork (2003), Chirinko and Wilson (2017), and Parchet (2019).

[21] See Lyttikäinen (2012) and Boning et al. (2023).

there is considerable evidence suggesting that international tax competition reduces corporate tax rates, it is unclear whether and to what extent countries may react to lower tax rates elsewhere by reducing their own.

8. Conclusion.

Tax competition that depresses rates creates an opportunity to advance collective objectives with coordinated action. In concept, one could adjust each country's tax rate to undo the effect of competition, which would entail differentiated adjustments to each. This is not what a minimum tax does. Minimum taxation instead bears only on the lowest-tax countries, requiring that they all impose the same tax rate, and does not address tax competition among other countries. As a result, efficient minimum tax rates balance the costs to low-tax countries of deviating from their preferred tax rates with the potential benefits to all of having higher average tax rates. Since higher minimum tax rates expand the range of affected countries, thereby affecting the impact of higher rates, there are dominated regions over which no minimum tax rate is efficient. While estimates for 2020 imply that minimum statutory corporate tax rates of 4% or less, and those of 27% or more, will represent efficient choices under some circumstances, the estimates also imply that there is no efficient minimum tax rate between 4% and 27%.

Minimum taxation holds undeniable appeal as an alternative to independent tax setting in the modern competitive environment. Many countries have eagerly embraced the OECD (2021) proposal to require that large corporations be taxed at a minimum rate of 15%, notwithstanding the possibility that 15% lies within the range of dominated tax rates. Minimum requirements also appear in other contexts, whenever central authorities are reluctant to grant subnational governments or other independent entities complete discretion over taxes, regulations, and other policy choices. The same Taylor approximations that facilitate inferences about corporate taxation can be used to evaluate minimum requirements in these other settings – and may yield the implication that common minimum requirements exhibit broad ranges of dominated values, as they appear to do with corporate taxes.

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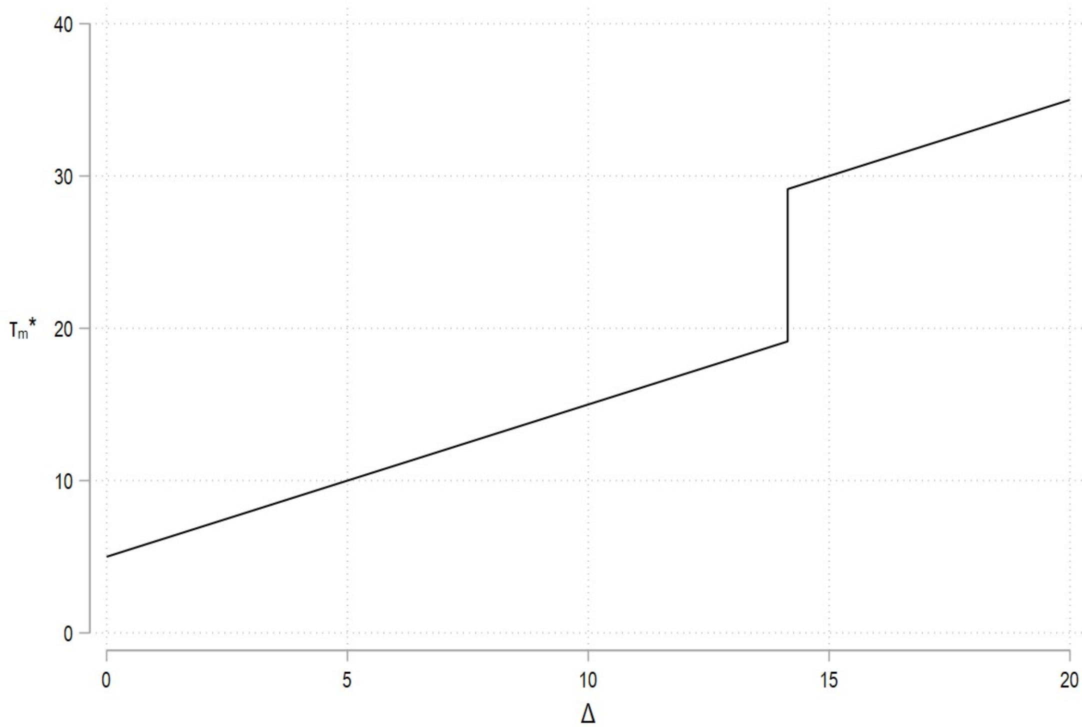
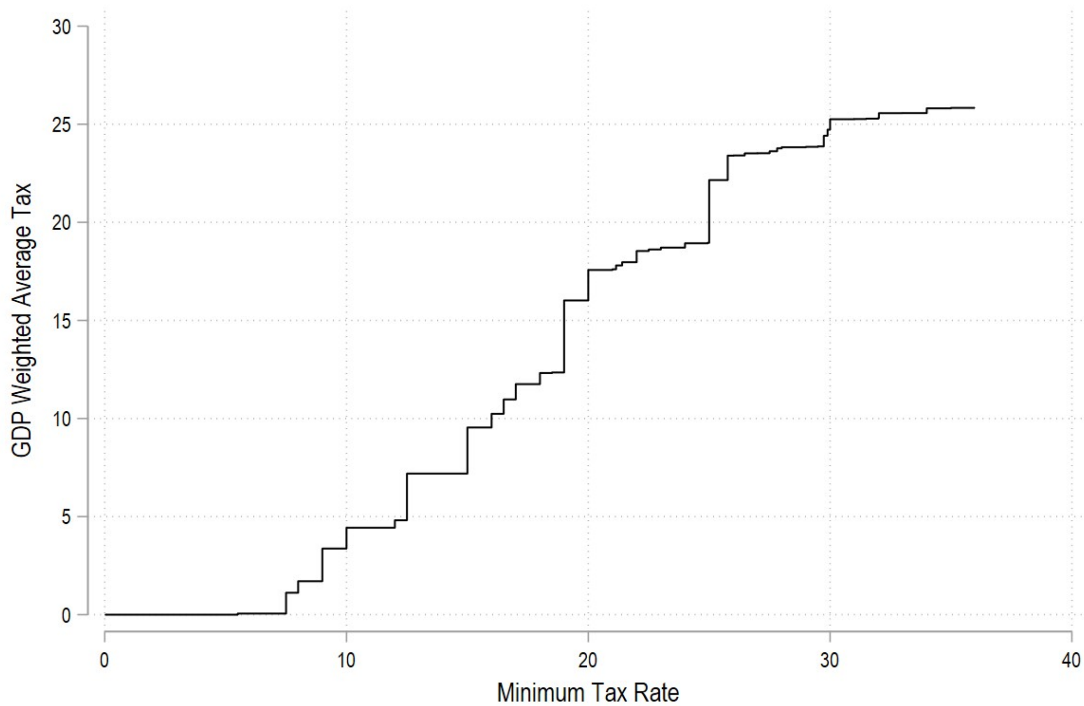
Figure 1
Efficient Minimum Taxes with a Bimodal Tax Distribution



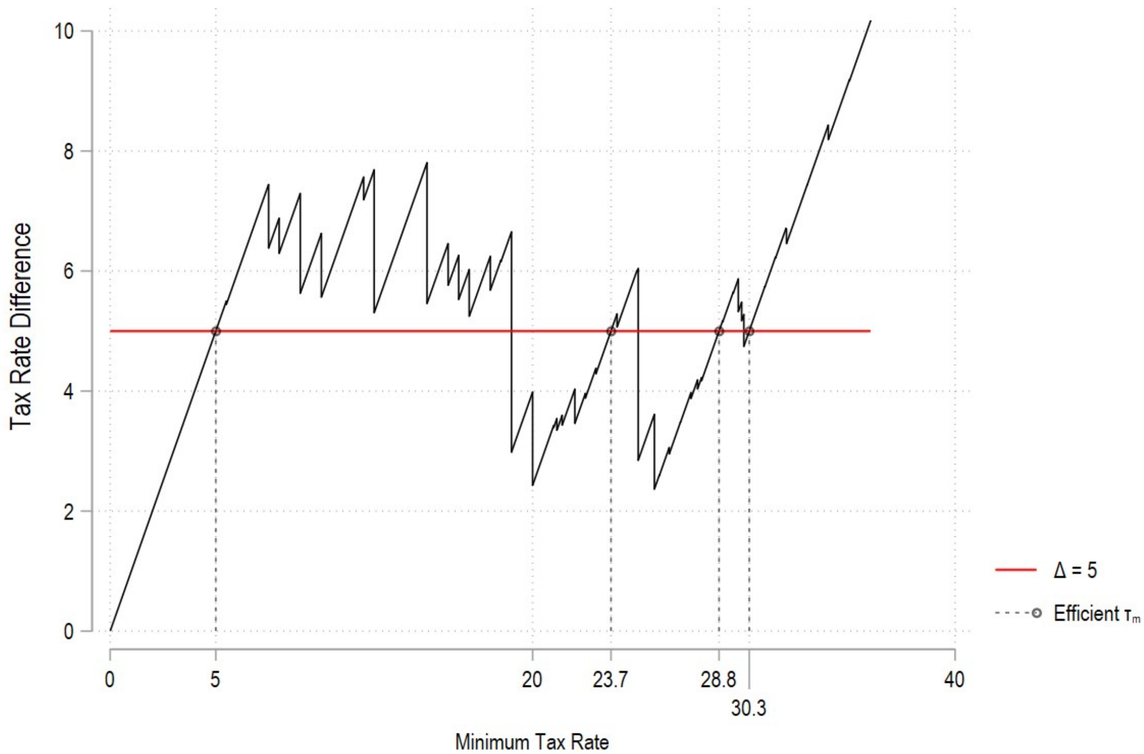
Note: The figure presents the efficient minimum tax rate, as a function of Δ, for the example in which half the world chooses a tax rate of 5% and half chooses a tax rate of 25%.

Figure 2
Average Tax Rates of Countries Constrained by Minimum Taxes, 2020



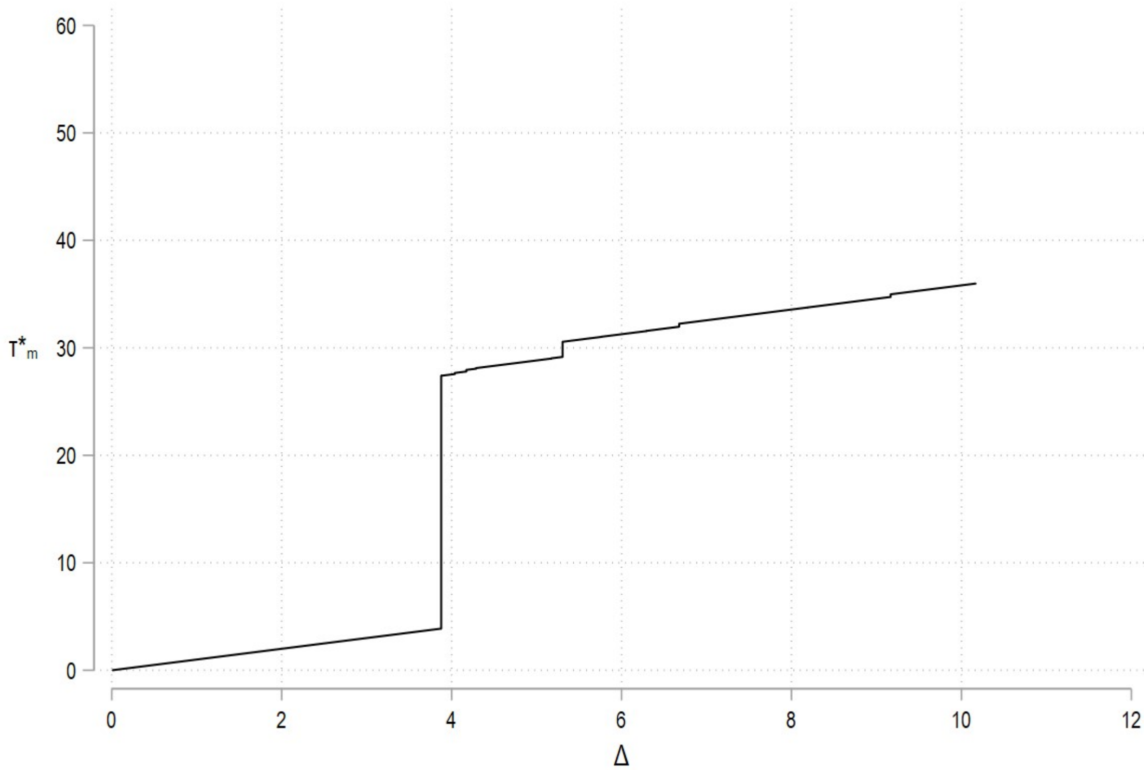
Note: the figure plots average 2020 statutory corporate tax rates, $\tilde{\tau}_B$, of countries with tax rates equal to or less than τ_m, with tax rates weighted by GDP.

Figure 3
Tax Rate Differences and Locally Efficient Minimums, 2020



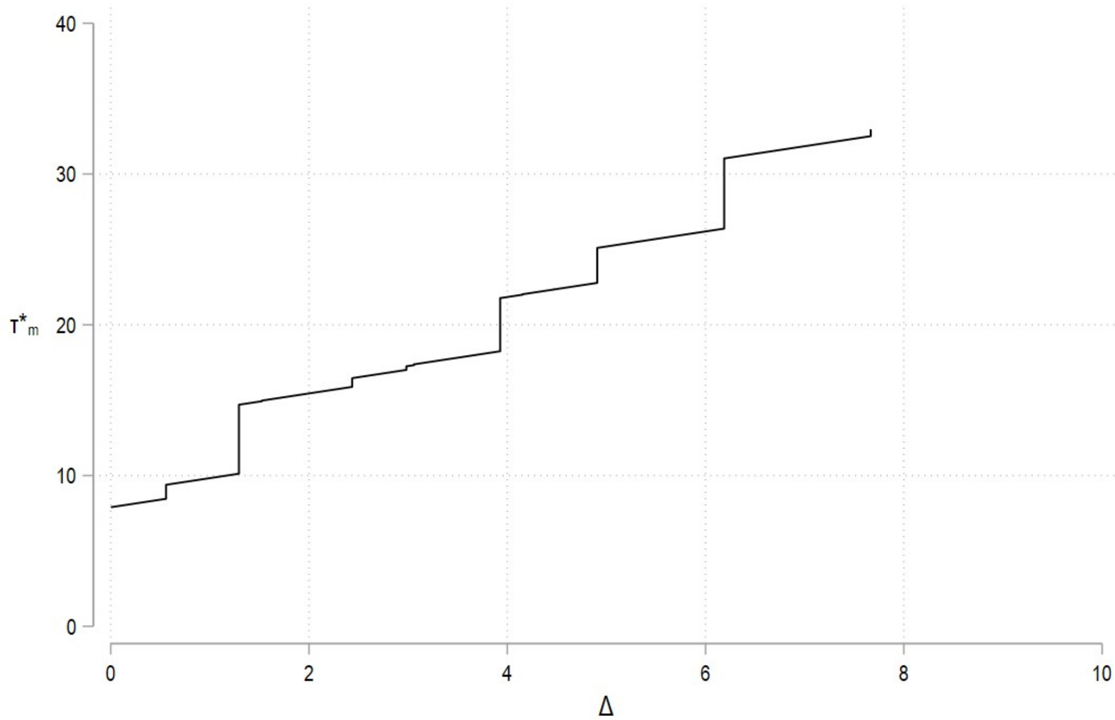
Note: the figure plots $\left(\tau_m - \tilde{\tau}_B\right)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using statutory corporate tax rates for 2020, weighted by GDP. The circles identify locally efficient tax rates (5%, 23.7%, 28.8%, and 30.3%) for $\Delta = 5$.

Figure 4
Efficient Minimum Tax Rates, 2020



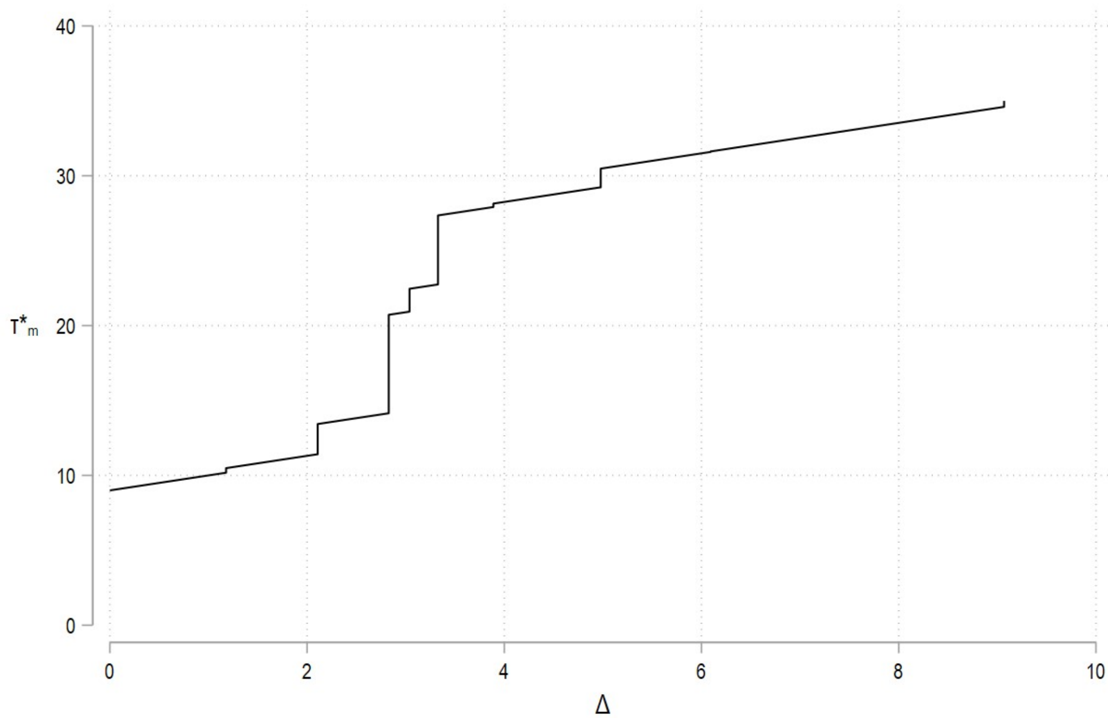
Note: The figure presents minimum statutory corporate tax rates that maximize GDP-weighted collective objectives at different values of Δ in 2020.

Figure 5
Efficient Minimum Effective Tax Rates, 35 Country Coalition, 2020



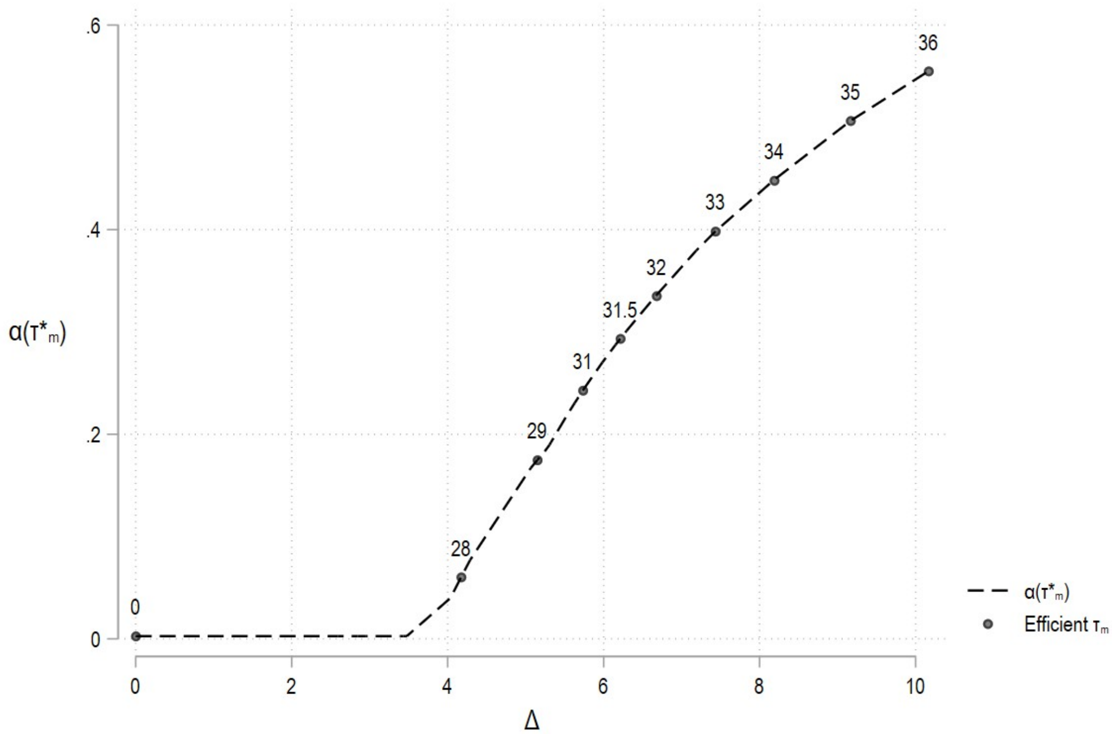
Note: The figure presents minimum effective corporate tax rates that maximize GDP-weighted collective objectives of the 35-country coalition at different values of Δ in 2020.

Figure 6
Efficient Minimum Statutory Tax Rates, 35 Country Coalition, 2020



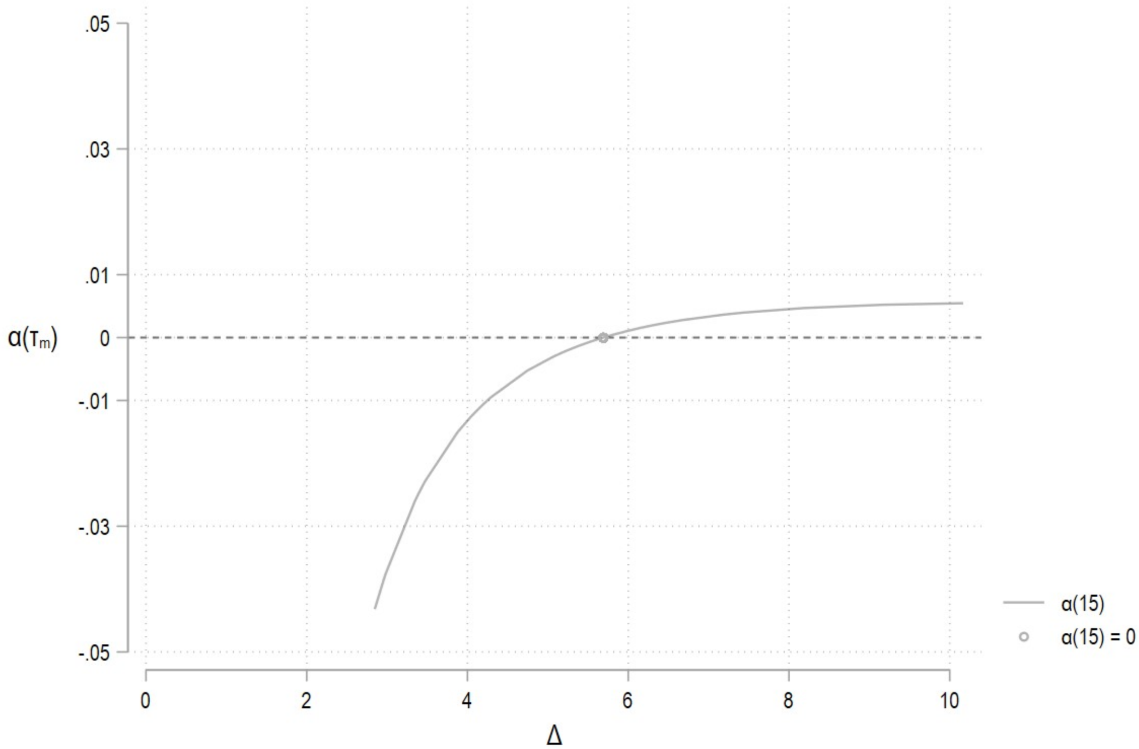
Note: The figure presents minimum statutory corporate tax rates that maximize GDP-weighted collective objectives of the 35-country coalition at different values of Δ in 2020.

Figure 7
Impact of Efficient Minimum Taxes, 2020



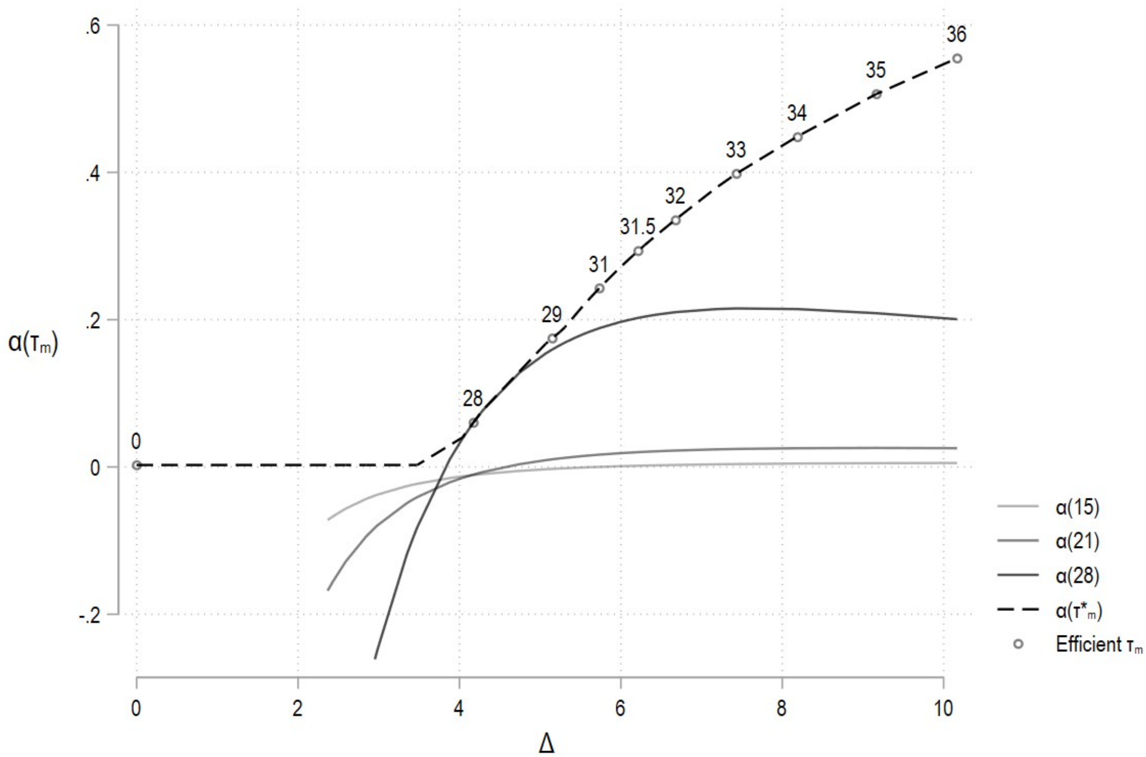
Note: the figure presents implied values of τ_m^* and $\alpha\left(\tau_m^*\right)$ at different levels of Δ, using 2020 GDP-weighted statutory corporate tax rates.

Figure 8
Impact of a 15% Minimum Tax, 2020



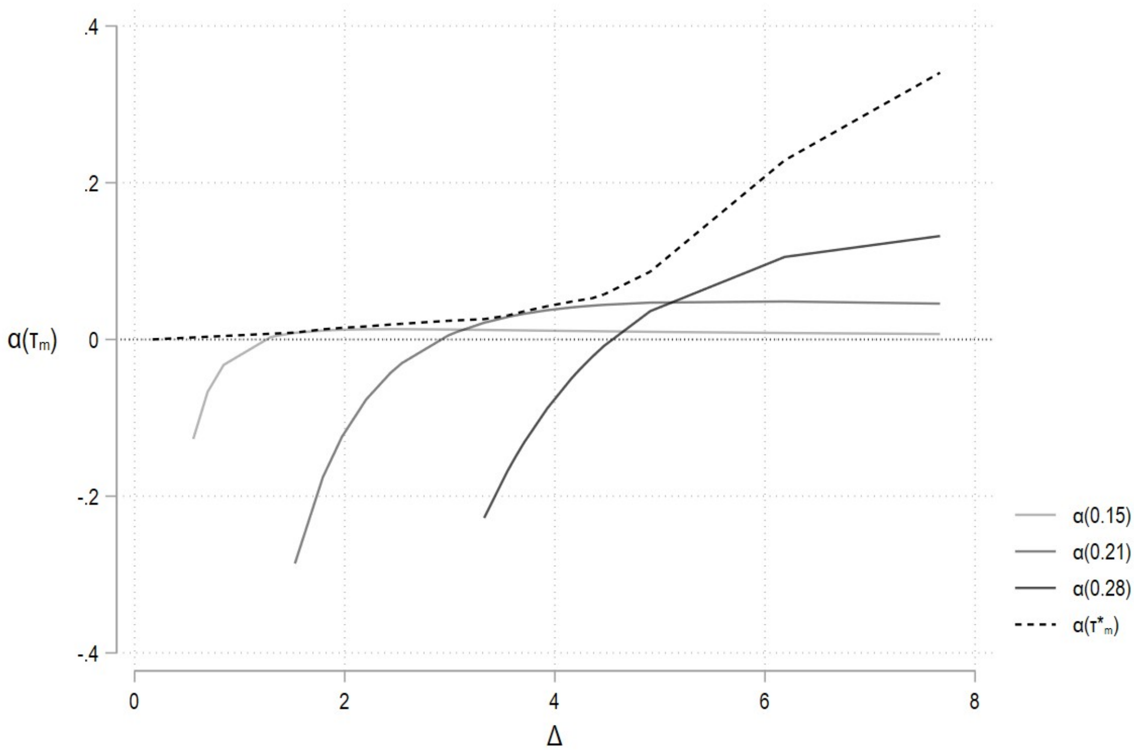
Note: the figure presents implied values of $\alpha(0.15)$ at different levels of Δ, using 2020 GDP-weighted statutory corporate tax rates.

Figure 9
Comparing the Impact of 15%, 21%, and 28% Minimum Taxes, 2020



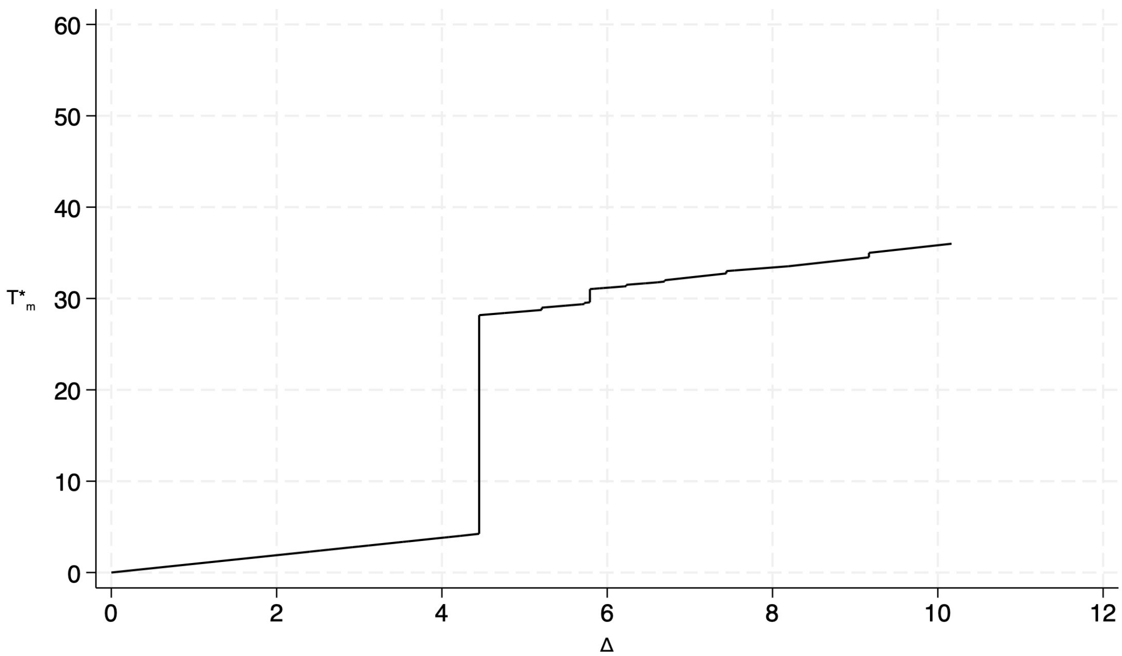
Note: the figure presents values of $\alpha\left(\tau_m\right)$ for minimum tax rates of 15%, 21%, and 28%, as well as $\alpha\left(\tau_m^*\right)$, at different levels of Δ, using 2020 GDP-weighted statutory corporate tax rates.

Figure 10
Comparing the Impact of 15%, 21%, and 28% Minimum Effective Taxes, 35 Country Coalition, 2020



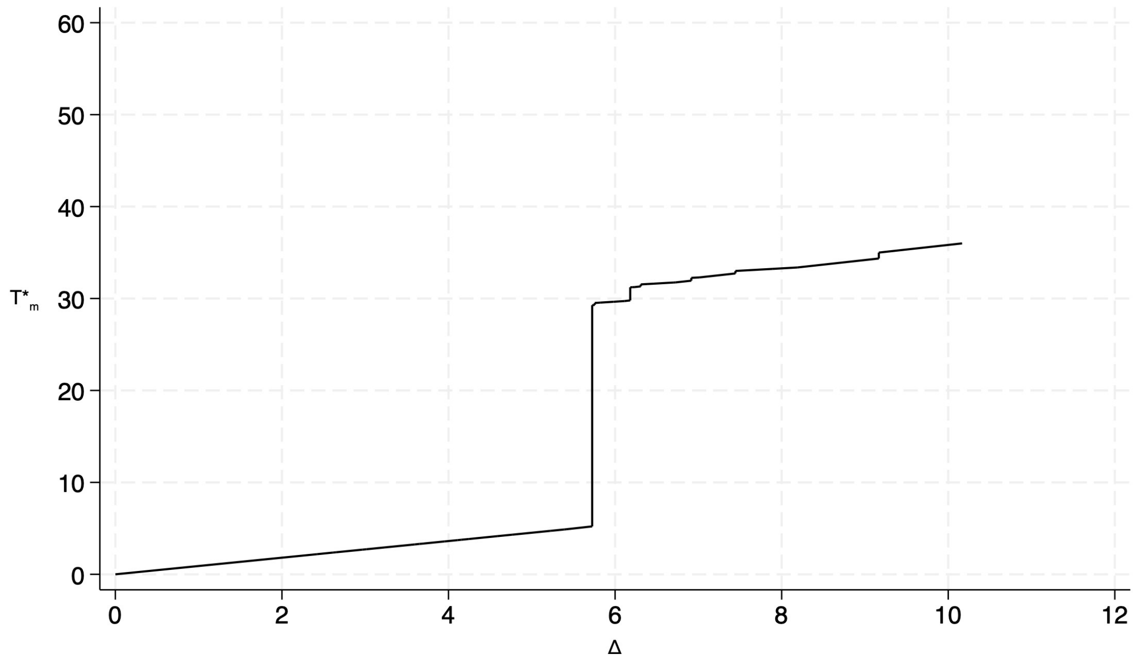
Note: the figure presents values of $\alpha\left(\tau_m\right)$ for minimum tax rates of 15%, 21%, and 28%, as well as $\alpha\left(\tau_m^*\right)$, for the 35 country coalition at different levels of Δ, using 2020 GDP-weighted effective corporate tax rates.

Figure 11
Efficient Minimum Tax Rates, Medium Strategic Complementarity, 2020



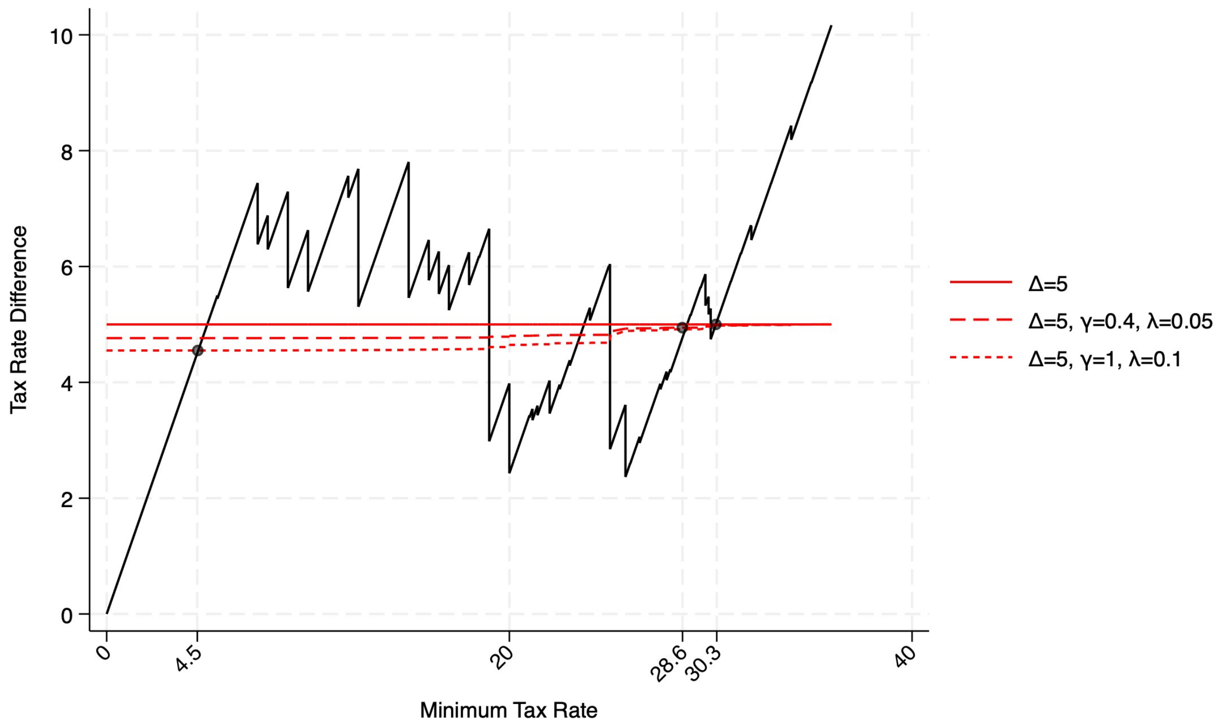
Note: The figure presents minimum statutory corporate tax rates that maximize GDP-weighted collective objectives at different values of Δ in 2020, with tax rate strategic complementarity characterized by $\gamma = 0.4$ and $\lambda = 0.05$, which imply that $d\tau_i / d\bar{\tau} = 0.3$.

Figure 12
Efficient Minimum Tax Rates, Strong Strategic Complementarity, 2020



Note: The figure presents minimum statutory corporate tax rates that maximize GDP-weighted collective objectives at different values of Δ in 2020, with tax rate strategic complementarity characterized by $\gamma = 1$ and $\lambda = 0.1$, which imply that $d\tau_i / d\overline{\tau} = 0.5$.

Figure 13
Tax Rate Differences and Locally Efficient Minimums, with and without Strategic Complementarity, 2020



Note: the figure plots $(\tau_m - \tilde{\tau}_B)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using statutory corporate tax rate data for 2020, weighted by GDP. The figure superimposes a line for $\Delta = 5$, and two additional schedules adjusting $\Delta = 5$ for strategic complementarity characterized by $d\tau_i / d\overline{\tau} = 0.3$ and $d\tau_i / d\overline{\tau} = 0.5$.

Appendix A

Part 1

The first part of this appendix offers derivations of conditions in section 2.3 of the text. Differentiating equation (1) with respect to $\overline{\tau}$,

(A1) $$\frac{\partial^2 O_i}{\partial \tau_i^2}\frac{d\tau_i}{d\overline{\tau}}+\frac{\partial^2 O_i}{\partial \tau_i \partial d_i}\left(\frac{d\tau_i}{d\overline{\tau}}-1\right)+\frac{\partial^2 O_i}{\partial d_i \partial \tau_i}\frac{d\tau_i}{d\overline{\tau}}+\frac{\partial^2 O_i}{\partial d_i^2}\left(\frac{d\tau_i}{d\overline{\tau}}-1\right)=0 .$$

Since $\frac{\partial^2 O_i}{\partial d_i \partial \tau_i}=\frac{\partial^2 O_i}{\partial \tau_i \partial d_i}$, (A1) implies that

(A2) $$\frac{d\tau_i}{d\overline{\tau}}=\frac{\frac{\partial^2 O_i}{\partial d_i^2}+\frac{\partial^2 O_i}{\partial \tau_i \partial d_i}}{\frac{\partial^2 O_i}{\partial \tau_i^2}+2\frac{\partial^2 O_i}{\partial \tau_i \partial d_i}+\frac{\partial^2 O_i}{\partial d_i^2}} .$$

In the special case in which $\frac{\partial^2 O_i}{\partial d_i^2}=\gamma\frac{\partial^2 O_i}{\partial \tau_i^2}$ and $\frac{\partial^2 O_i}{\partial \tau_i \partial d_i}=\lambda\frac{\partial^2 O_i}{\partial \tau_i^2}$, then (A2) implies

(A3) $$\frac{d\tau_i}{d\overline{\tau}}=\frac{\gamma+\lambda}{1+2\lambda+\gamma} .$$

Part 2

The second part of this appendix considers the value of $\frac{d\overline{\tau}_m}{d\tau_m}$. Since $\overline{\tau}_m=\sum_A \hat{\tau}_i v_i+\sum_B \tau_m v_i$, follows that

(A4) $$\frac{d\overline{\tau}_m}{d\tau_m}=\sum_A \frac{d\hat{\tau}_i}{d\overline{\tau}_m}\frac{d\overline{\tau}_m}{d\tau_m}v_i+\sum_B v_i .$$

Consequently, if $\frac{d\tau_i}{d\overline{\tau}} = \frac{d\hat{\tau}_i}{d\overline{\tau}_m} = 0$, then $\frac{d\overline{\tau}_m}{d\tau_m} = \sum_B \nu_i$. Otherwise,

(A5) $$\frac{d\overline{\tau}_m}{d\tau_m} = \frac{\sum_B \nu_i}{\left(1 - \sum_A \frac{d\hat{\tau}_i}{d\overline{\tau}_m} \nu_i\right)}.$$

The analysis in section 5 of the paper takes strategic reactions to be constant; adopting this assumption, then (A3) implies that $\frac{d\hat{\tau}_i}{d\overline{\tau}_m} = \frac{\gamma + \lambda}{1 + 2\lambda + \gamma}$. From the definition of ψ, $\sum_B \nu_i = \psi \frac{\sum_B \theta_i w_i}{\sum \theta_i w_i}$; and from the definition of competition weights, $\sum_A \nu_i = 1 - \sum_B \nu_i$. These conditions, together with (A5), imply that

(A6) $$\frac{d\overline{\tau}_m}{d\tau_m} = \frac{\psi \sum_B \theta_i w_i / \sum \theta_i w_i}{\left[1 - \left(1 - \psi \sum_B \theta_i w_i / \sum \theta_i w_i\right) \frac{(\lambda + \gamma)}{(1 + 2\lambda + \gamma)}\right]}.$$

Appendix B

This appendix offers a derivation of equation (12) in the text. This equation comes from evaluating (11), which is reproduced as

(B1) $$M\left(\tau_m\right)-S=\int_0^{\tau_m}\left[-\sum_B \theta_i w_i\right]\left[\Delta\psi-\left(\tau_m-\tilde{\tau}_B\right)\right]dz .$$

The first term on the right side of (B1) is $\int_0^{\tau_m}\left[-\sum_B \theta_i w_i\right]\Delta\psi dz$, which from the definition of ψ can be rewritten as $\left[-\sum \theta_i w_i\right]\Delta\int_0^{\tau_m}\sum_B v_i dz$. Applying integration by parts, and using the definition $\overline{\tau}_B \equiv \frac{\sum_B \tau_i v_i}{\sum_B v_i}$, it follows that

(B2) $$\int_0^{\tau_m}\sum_B v_i dz=\tau_m\sum_B v_i-\int_0^{\tau_m}\tau_i v_i dz=\left(\tau_m-\overline{\tau}_B\right)\sum_B v_i .$$

Consequently,

(B3) $$\int_0^{\tau_m}\left[-\sum_B \theta_i w_i\right]\Delta\psi dz=\left[-\sum \theta_i w_i\right]\Delta\left(\tau_m-\overline{\tau}_B\right)\sum_B v_i=-\left(\tau_m-\overline{\tau}_B\right)\Delta\psi\sum_B \theta_i w_i .$$

The second term on the right side of (B1) is $\int_0^{\tau_m}\left[-\sum_B \theta_i w_i\right]\tau_m dz$. Integrating this expression by parts,

(B4) $$\int_0^{\tau_m}\left[-\sum_B \theta_i w_i\right]\tau_m dz=\frac{\tau_m^2}{2}\left[-\sum_B \theta_i w_i\right]+\int_0^{\tau_m}\frac{\tau_i^2}{2}\theta_i w_i dz=\frac{\left[-\sum_B \theta_i w_i\right]}{2}\left(\tau_m^2-\frac{\sum_B \tau_i^2\theta_i w_i}{\sum_B \theta_i w_i}\right).$$

The third term on the right side of (B1) is $\int_0^{\tau_m}\left[-\sum_B \theta_i w_i\right]\tilde{\tau}_B dz$. Integrating this expression by parts,

(B5) $$\int_0^{\tau_m}\left[-\sum_B \theta_i w_i\right]\tilde{\tau}_B dz=\left[-\sum_B \theta_i w_i\right]\tau_m\tilde{\tau}_B+\int_0^{\tau_m}\tau_i^2\theta_i w_i dz=\left[-\sum_B \theta_i w_i\right]\left[\tau_m\tilde{\tau}_B-\frac{\sum_B \tau_i^2\theta_i w_i}{\sum_B \theta_i w_i}\right].$$

Combining (B1), (B3), (B4), and (B5),

(B6) $$M\left(\tau_m\right)-S=\left[-\sum\nolimits_B \theta_i w_i\right]\left[\left(\tau_m-\overline{\tau}_B\right)\Delta\psi+\tau_m\tilde{\tau}_B-\frac{\tau_m^2}{2}-\frac{1}{2}\frac{\sum_B \tau_i^2\theta_i w_i}{\sum_B \theta_i w_i}\right].$$

Defining of the weighted variance of group-B tax rates as

$\sigma_B^2 \equiv \frac{\sum_B\left(\tau_i-\tilde{\tau}_B\right)^2\theta_i w_i}{\sum_B \theta_i w_i}=\frac{\sum_B \tau_i^2\theta_i w_i}{\sum_B \theta_i w_i}-\tilde{\tau}_B^2$, (B6) implies that

(B7) $$M\left(\tau_m\right)-S=\frac{-1}{2}\left[\left(\Delta\psi+\left(\tilde{\tau}_B-\overline{\tau}_B\right)\right)^2-\left(\tau_m-\left(\Delta\psi+\tilde{\tau}_B\right)\right)^2-\left(\tilde{\tau}_B-\overline{\tau}_B\right)^2-\sigma_B^2\right]\sum\nolimits_B \theta_i w_i\ ,$$

which is identical to equation (12) in the text of the paper.

Appendix C

This appendix considers the possibility of $M'(\tau_m)$ transitioning from negative to positive as τ_m increases, in a setting with a continuous distribution of countries and tax rates. From (9), the sign of $M'(\tau_m)$ is the sign of $\left[\Delta\psi-(\tau_m-\tilde{\tau}_B)\right]$. With an unchanging ψ, and a judiciously chosen $\Delta\psi$, this expression will change sign from negative to positive as τ_m increases over any range for which $\frac{\partial\tilde{\tau}_B}{\partial\tau_m}>1$.

If $f(z)$ is the (weighted) density of countries with tax rate *z*, it follows that

(C1) $$\tilde{\tau}_B=\frac{\int_0^{\tau_m} zf(z)dz}{\int_0^{\tau_m} f(z)dz}.$$

Differentiating this expression,

(C2) $$\frac{\partial\tilde{\tau}_B}{\partial\tau_m}=\frac{(\tau_m-\tilde{\tau}_B)f(\tau_m)}{\int_0^{\tau_m} f(z)dz}.$$

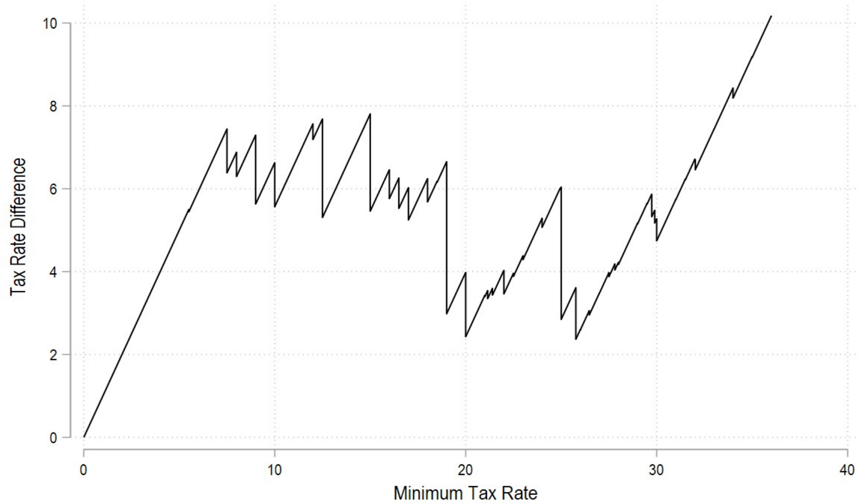
If $\overline{f}(\tau_m)$ is the average tax rate density over the the $[0,\tau_m]$ range, then the denominator of the right side of (C2) is $\tau_m\overline{f}(\tau_m)$. Consequently, $\frac{\partial\tilde{\tau}_B}{\partial\tau_m}=\frac{(\tau_m-\tilde{\tau}_B)f(\tau_m)}{\tau_m\overline{f}(\tau_m)}$, and $\frac{\partial\tilde{\tau}_B}{\partial\tau_m}>1$ if

(C3) $$\frac{f(\tau_m)}{\overline{f}(\tau_m)}>\frac{\tau_m}{\tau_m-\tilde{\tau}_B}.$$

Expression (C3) indicates that $\frac{\partial\tilde{\tau}_B}{\partial\tau_m}>1$ if there is an unusually heavy concentration of tax rates at τ_m. As a result, if (C3) is satisfied, then at certain values of $\Delta\psi$, $M'(\tau_m)$ will transition from negative to positive as τ_m increases.

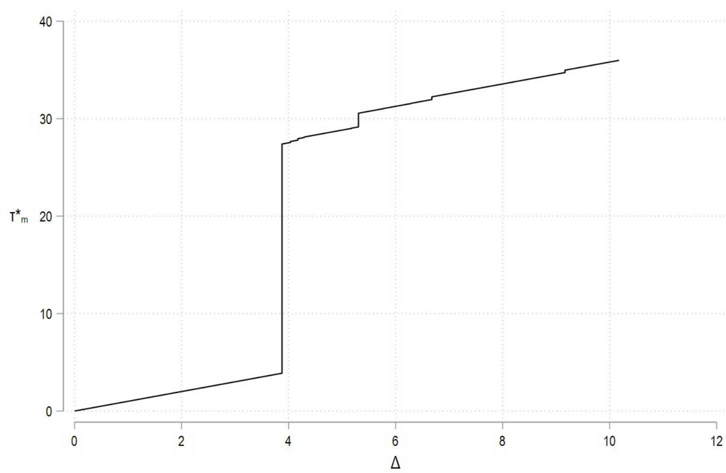
Appendix D.1

Figure D.1.a
Tax Rate Differences, Population Weights, 2020



Note: the figure plots $\left(\tau_m - \tilde{\tau}_B\right)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using 2020 population-weighted statutory corporate tax rates.

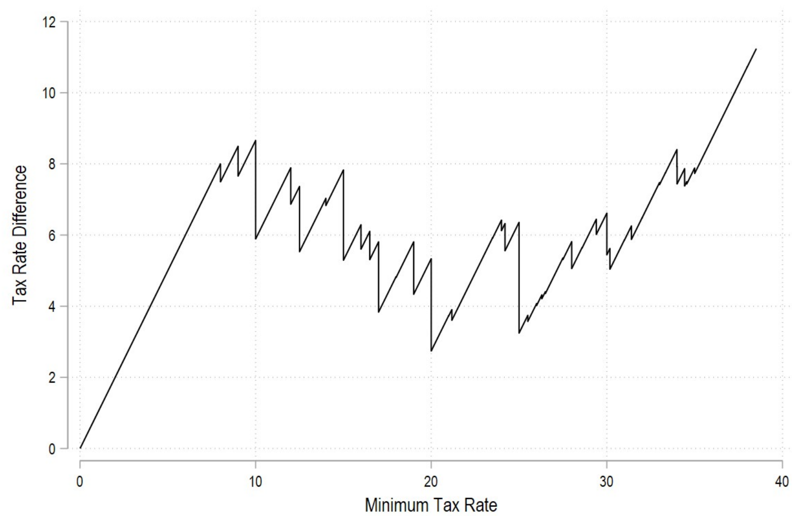
Figure D.1.b
Efficient Minimum Tax Rates, Population Weights, 2020



Note: The figure presents minimum statutory corporate tax rates that maximize population-weighted collective objectives for different values of Δ in 2020.

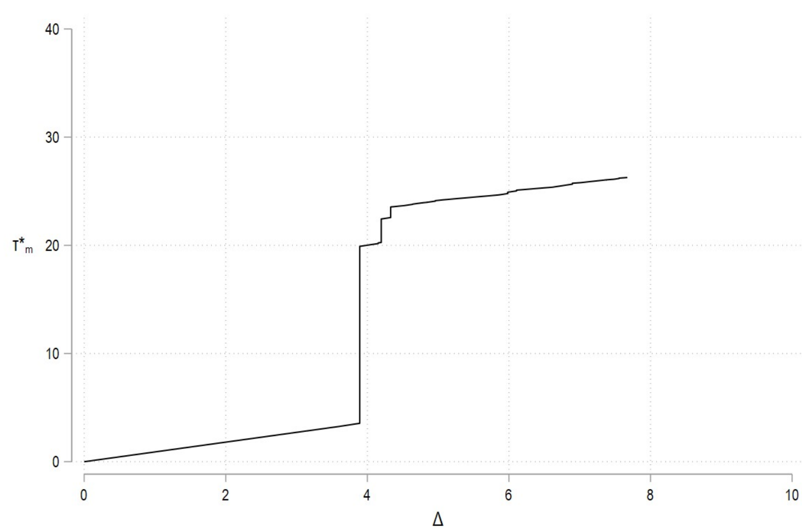
Appendix D.2

Figure D.2.a
Tax Rate Differences, 2010



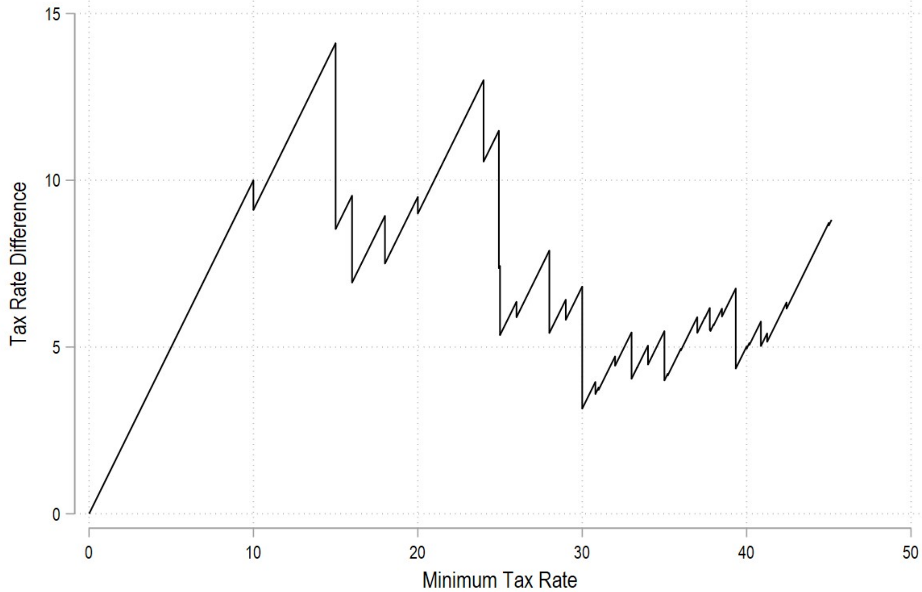
Note: the figure plots $\left(\tau_m - \tilde{\tau}_B\right)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using 2010 GDP-weighted statutory corporate tax rates.

Figure D.2.b
Efficient Minimum Tax Rates, 2010



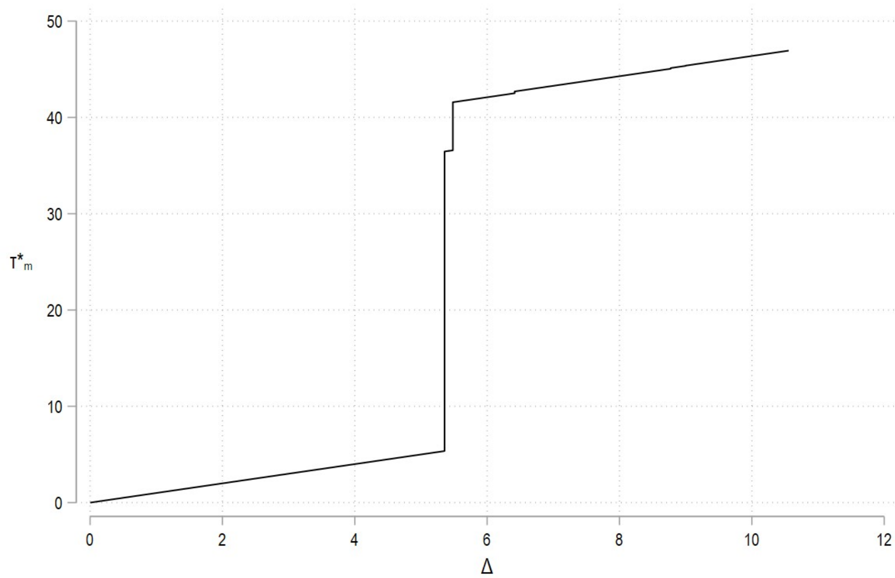
Note: The figure presents minimum statutory corporate tax rates that maximize GDP-weighted collective objectives at different values of Δ in 2010.

Figure D.2.c
Tax Rate Differences, 2000



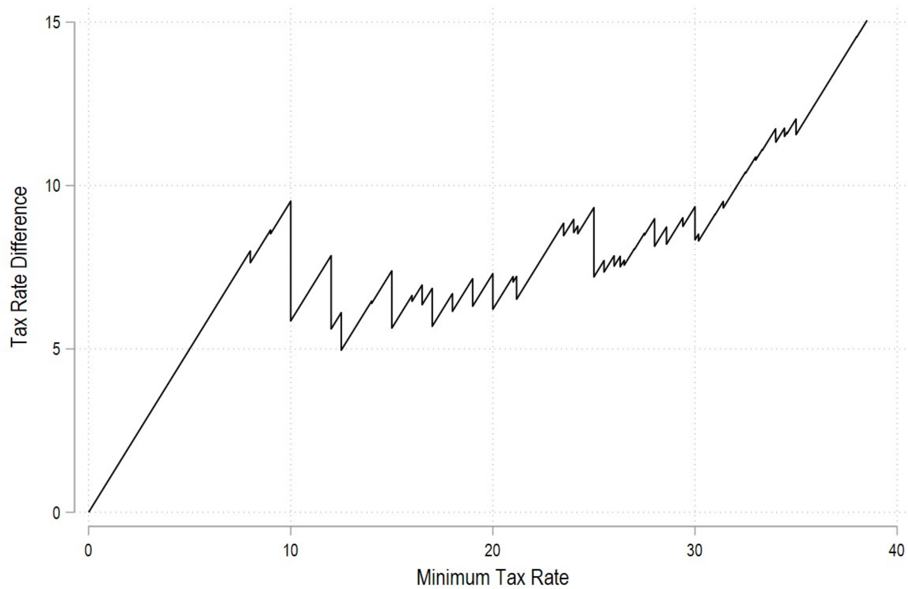
Note: the figure plots $\left(\tau_m - \tilde{\tau}_B\right)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using 2000 GDP-weighted statutory corporate tax rates.

Figure D.2.d
Efficient Minimum Tax Rates, 2000



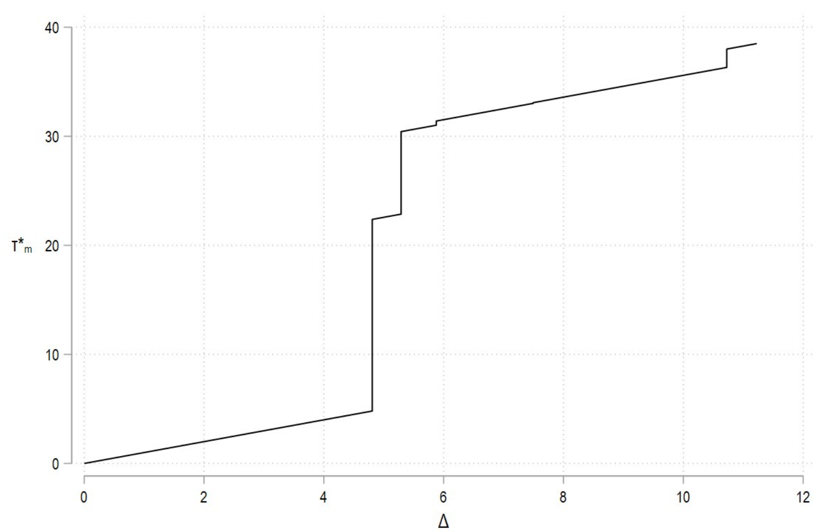
Note: The figure presents minimum statutory corporate tax rates that maximize GDP-weighted collective objectives at different values of Δ in 2000.

Figure D.2.e
Tax Rate Differences, Population Weights, 2010



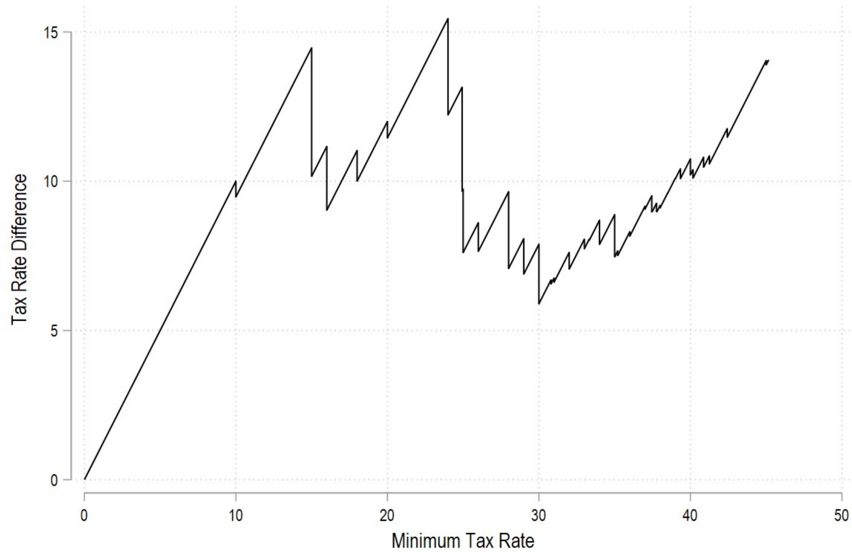
Note: the figure plots $\left(\tau_m - \tilde{\tau}_B\right)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using 2010 population-weighted statutory corporate tax rates.

Figure D.2.f
Efficient Minimum Tax Rates, Population Weights, 2010



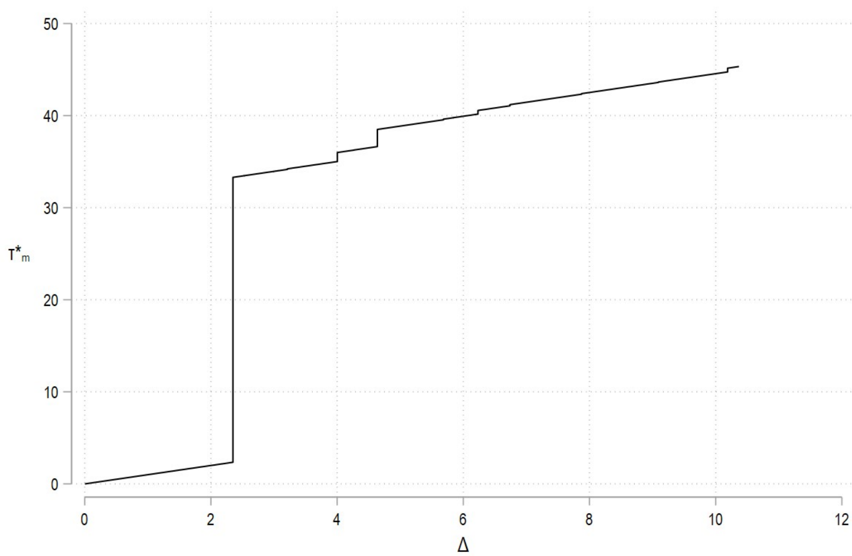
Note: The figure presents minimum statutory corporate tax rates that maximize population-weighted collective objectives at different values of Δ in 2010.

Figure D.2.g
Tax Rate Differences, Population Weights, 2000



Note: the figure plots $\left(\tau_m - \tilde{\tau}_B\right)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using 2000 population-weighted statutory corporate tax rates.

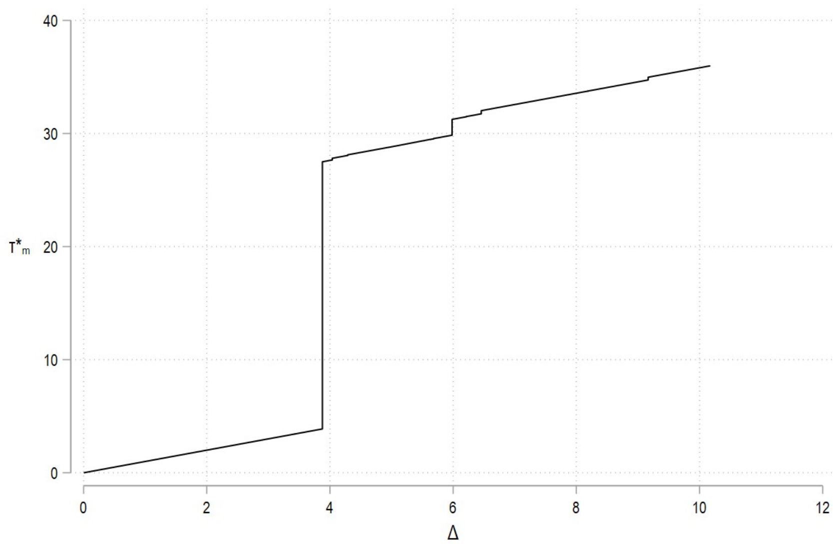
Figure D.2.h
Efficient Minimum Tax Rates, Population Weights, 2000



Note: The figure presents minimum statutory corporate tax rates that maximize population-weighted collective objectives at different values of Δ in 2000.

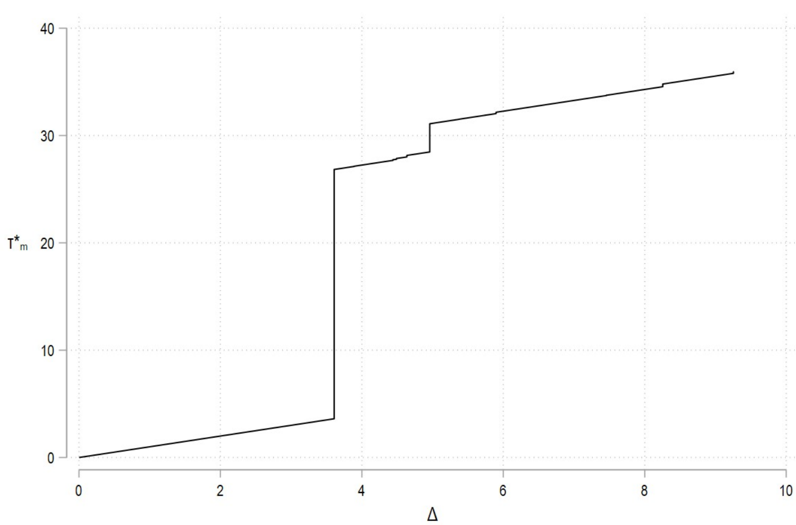
Appendix D.3

Figure D.3.a
Efficient Minimum Tax Rates, Population ν_i, 2020



Note: The figure presents minimum statutory corporate tax rates that maximize GDP-weighted collective objectives at different values of Δ in 2020, using population weights for ν_i.

Figure D.3.b
Efficient Minimum Tax Rates, Population Weights, Population ν_i, 2020

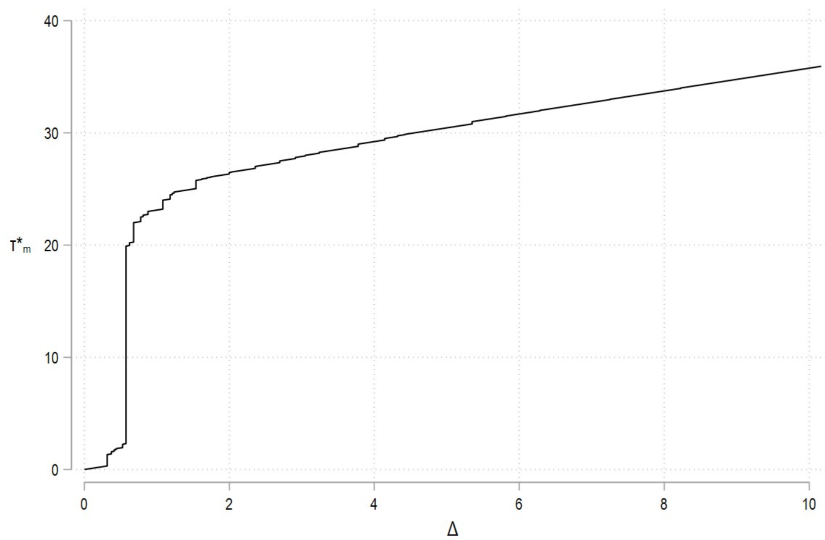


Note: The figure presents minimum statutory corporate tax rates that maximize 2020 population-weighted collective objectives at different values of Δ in 2020, using population weights for ν_i.

Appendix D.4

This appendix considers cases in which countries construct d_i by comparing their tax rates to the average tax rate available in tax havens, thereby excluding consideration of all other countries. Assigning the v_i weights to be equal to GDP for the tax haven countries identified in Hines (2010), and zero for all other countries, produces the schedule of efficient minimum tax rates depicted in Figure D.4.

Figure D.4
Efficient Minimum Tax Rates, Tax Haven Weights for v_i



Note: The figure presents minimum statutory corporate tax rates that maximize GDP-weighted collective objectives at different values of Δ in 2020, using tax haven GDP weights for v_i.

Separately, countries might instead construct d_i by comparing their tax rates only to tax havens with zero tax rates. In this scenario, $\sum_B v_i = 1$, so $\psi = \sum \theta_i w_i \Big/ \sum_B \theta_i w_i$, and (9) becomes

(D.4.1) $$M'(\tau_m) = \left[-\sum \theta_i w_i\right]\left[\Delta - (\tau_m - \tilde{\tau}_B)\frac{\sum_B \theta_i w_i}{\sum \theta_i w_i}\right].$$

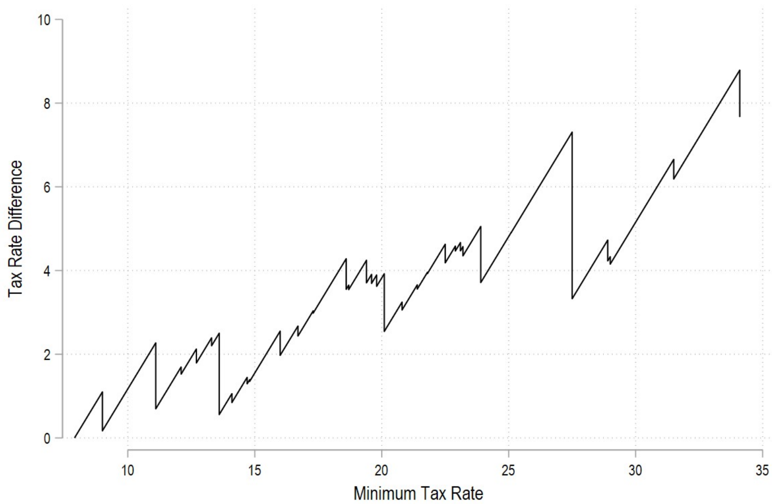
From the definition of $\tilde{\tau}_B$, $\left(\tau_m - \tilde{\tau}_B\right)\sum_B \theta_i w_i = \sum_B \left(\tau_m - \tau_i\right)\theta_i w_i$, so (D.4.1) can be rewritten

(D.4.2) $$M'\left(\tau_m\right) = \left[-\sum \theta_i w_i\right]\left[\Delta - \frac{\sum_B \left(\tau_m - \tau_i\right)\theta_i w_i}{\sum \theta_i w_i}\right].$$

Since $\frac{\sum_B \left(\tau_m - \tau_i\right)\theta_i w_i}{\sum \theta_i w_i}$ is uniformly increasing in τ_m, it follows from (D.4.2) that $M'\left(\tau_m\right)$ is uniformly decreasing. Consequently, for any value of Δ there is only a single τ_m at which $M'\left(\tau_m\right) = 0$, thereby ruling out this potential source of discontinuous jumps in the efficient minimum tax rate. The assumption that countries compare their tax rates only to tax havens with zero tax rates implies that the marginal benefit of raising the minimum tax rate remains constant over its range, rather than increasing as the minimum tax rate bears on additional countries; whereas the marginal cost of raising the minimum tax rate continually increases. In the context of equation (9), the second term of which is $\left[\Delta\psi - \left(\tau_m - \tilde{\tau}_B\right)\right]$, an unusually heavy concentration of tax rates at τ_m will reduce $\left(\tau_m - \tilde{\tau}_B\right)$, but also reduces ψ, as a result of which $M'\left(\tau_m\right)$ continues to decrease in τ_m.

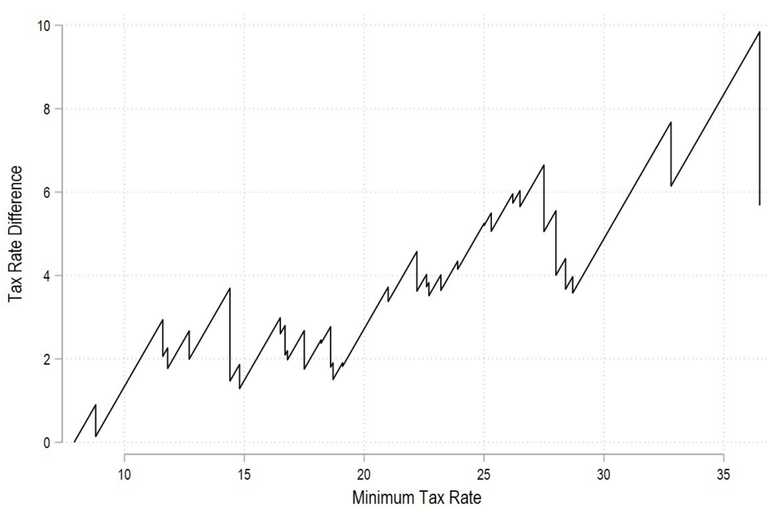
Appendix D.5

Figure D.5.a
Effective Tax Rate Differences, 35 Country Coalition, 2020



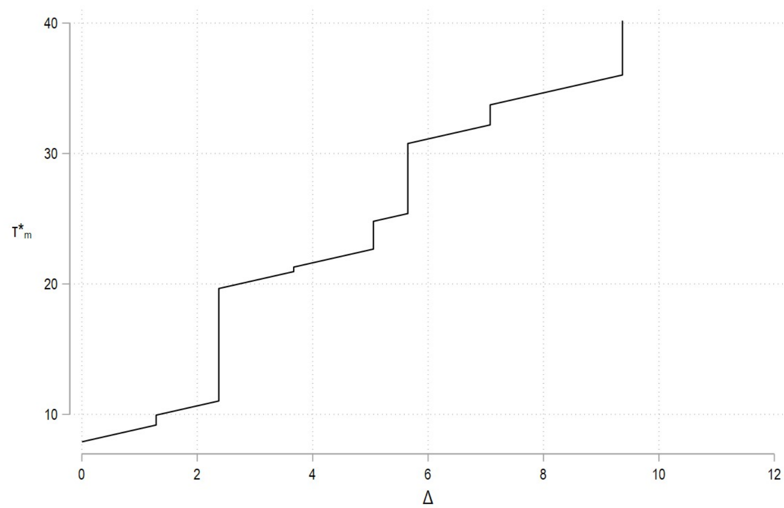
Note: the figure plots $\left(\tau_m - \tilde{\tau}_B\right)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using 2020 GDP-weighted effective corporate tax rates of the 35 country coalition.

Figure D.5.b
Effective Tax Rate Differences, 35 Country Coalition, 2010



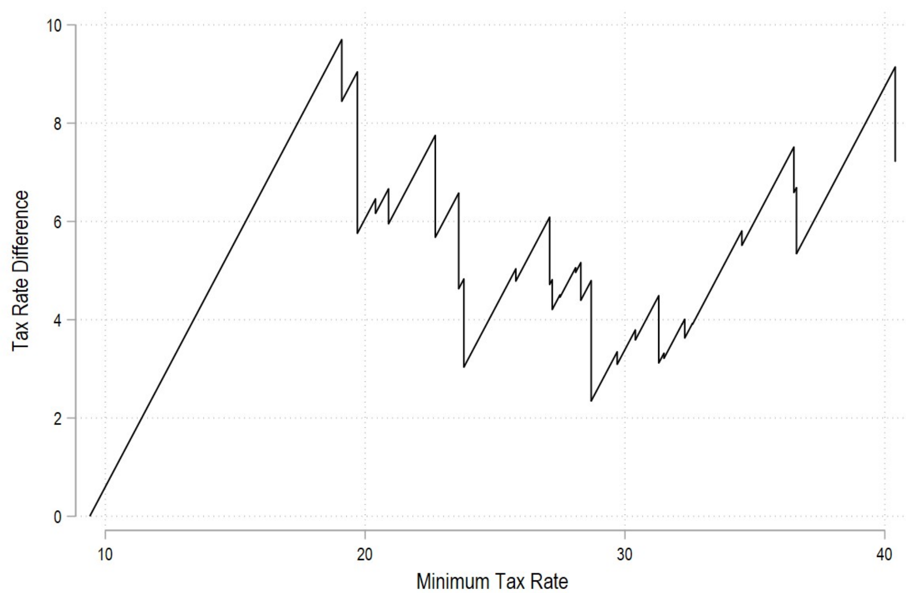
Note: the figure plots $\left(\tau_m - \tilde{\tau}_B\right)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using 2010 GDP-weighted effective corporate tax rates of the 35 country coalition.

Figure D.5.c
Efficient Minimum Effective Tax Rates, 35 Country Coalition, 2010



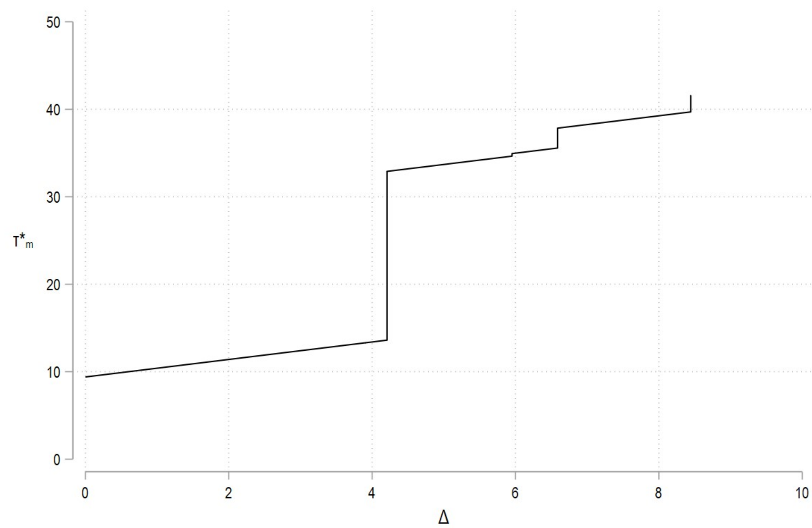
Note: The figure presents minimum effective corporate tax rates that maximize GDP-weighted collective objectives of the 35 country coalition at different values of Δ in 2010.

Figure D.5.d
Effective Tax Rate Differences, 28 Country Coalition, 2000



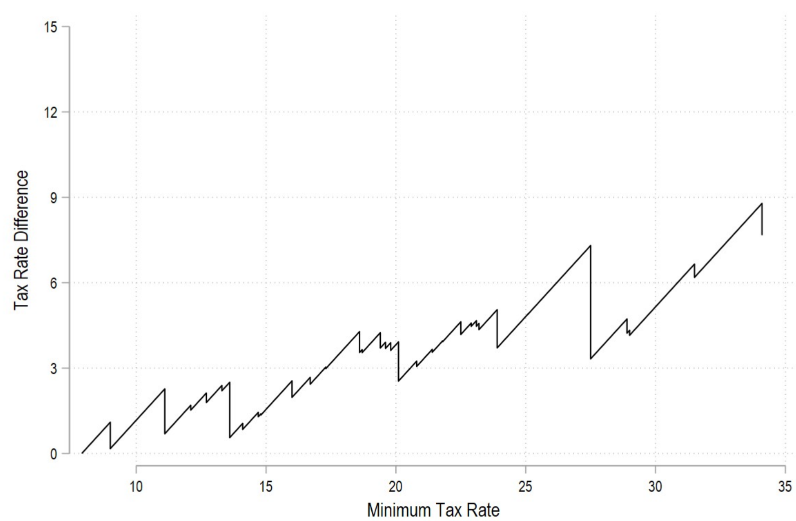
Note: the figure plots $\left(\tau_m - \tilde{\tau}_B\right)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using 2000 GDP-weighted effective corporate tax rates of the 28 country coalition.

Figure D.5.e
Efficient Minimum Effective Tax Rates, 28 Country Coalition, 2000



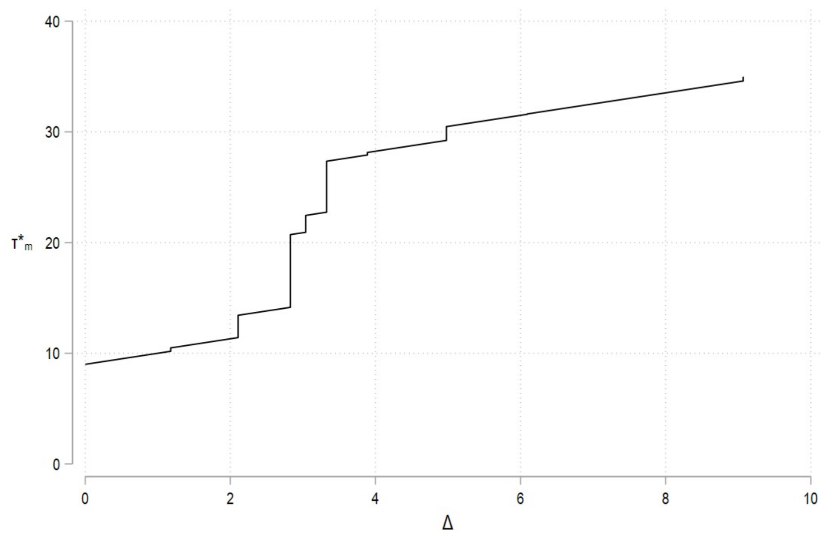
Note: The figure presents minimum effective corporate tax rates that maximize GDP-weighted collective objectives of the 28 country coalition at different values of Δ in 2000.

Figure D.5.f
Effective Tax Rate Differences, Population Weights, 35 Country Coalition, 2020



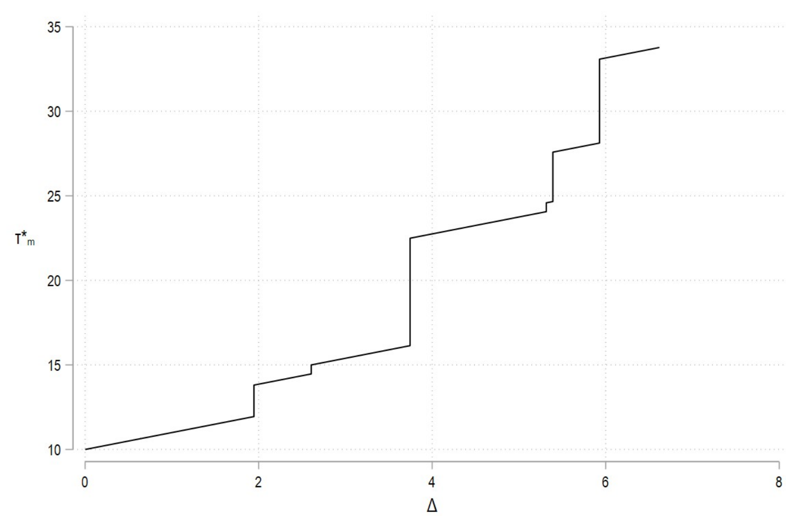
Note: the figure plots $\left(\tau_m - \tilde{\tau}_B\right)$ for different possible values of τ_m, calculating $\tilde{\tau}_B$ using 2020 population-weighted effective corporate tax rates of the 35 country coalition.

Figure D.5.g
Efficient Minimum Effective Tax Rates, Population Weights, 35 Country Coalition, 2020



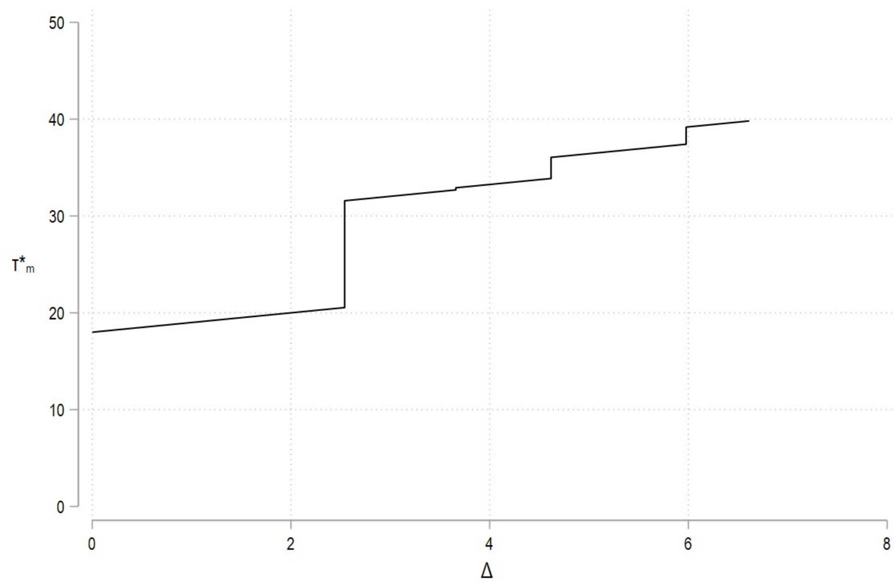
Note: The figure presents minimum effective corporate tax rates that maximize population-weighted collective objectives of the 35-country coalition at different values of Δ in 2020.

Figure D.5.h
Efficient Minimum Statutory Tax Rates, 35 Country Coalition, 2010



Note: The figure presents minimum statutory corporate tax rates that maximize GDP-weighted collective objectives of the 35-country coalition at different values of Δ in 2010.

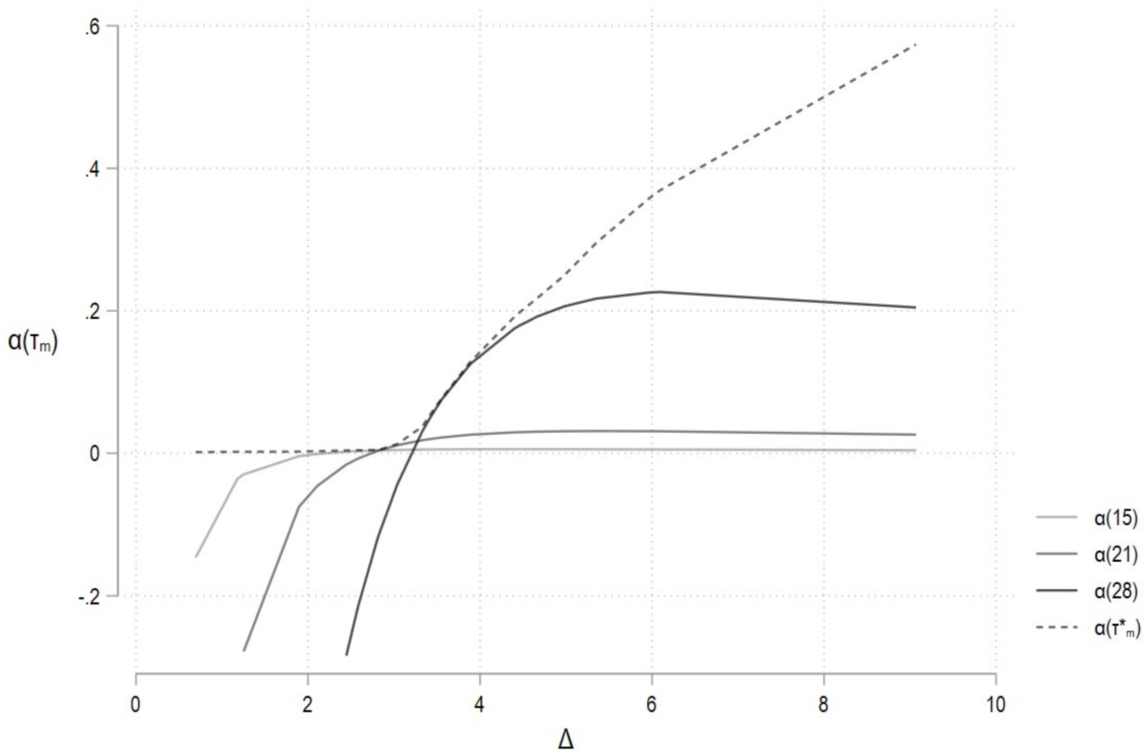
Figure D.5.i
Efficient Minimum Statutory Tax Rates, 28 Country Coalition, 2000



Note: The figure presents minimum statutory corporate tax rates that maximize GDP-weighted collective objectives of the 28-country coalition at different values of Δ in 2000.

Appendix D.6

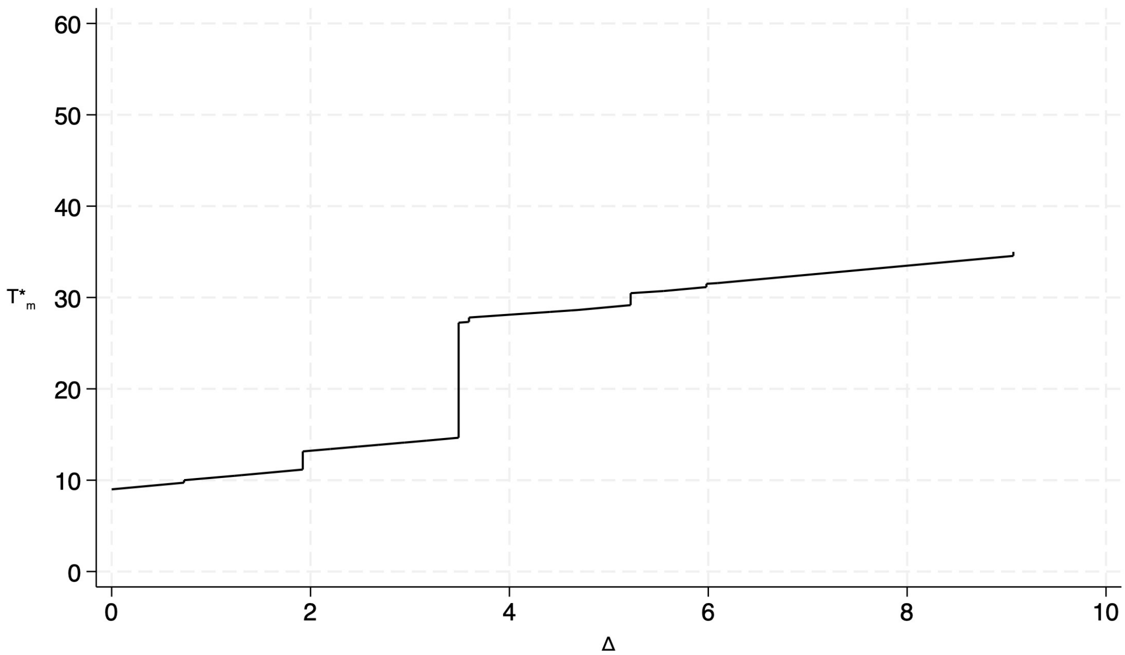
Figure D.6
Comparing the Impact of 15%, 21%, and 28% Minimum Statutory Taxes, 35 Country Coalition, 2020



Note: the figure presents values of $\alpha\left(\tau_m\right)$ for minimum tax rates of 15%, 21%, and 28%, as well as $\alpha\left(\tau_m^*\right)$, for the 35-country coalition at different levels of Δ, using 2020 GDP-weighted statutory corporate tax rates.

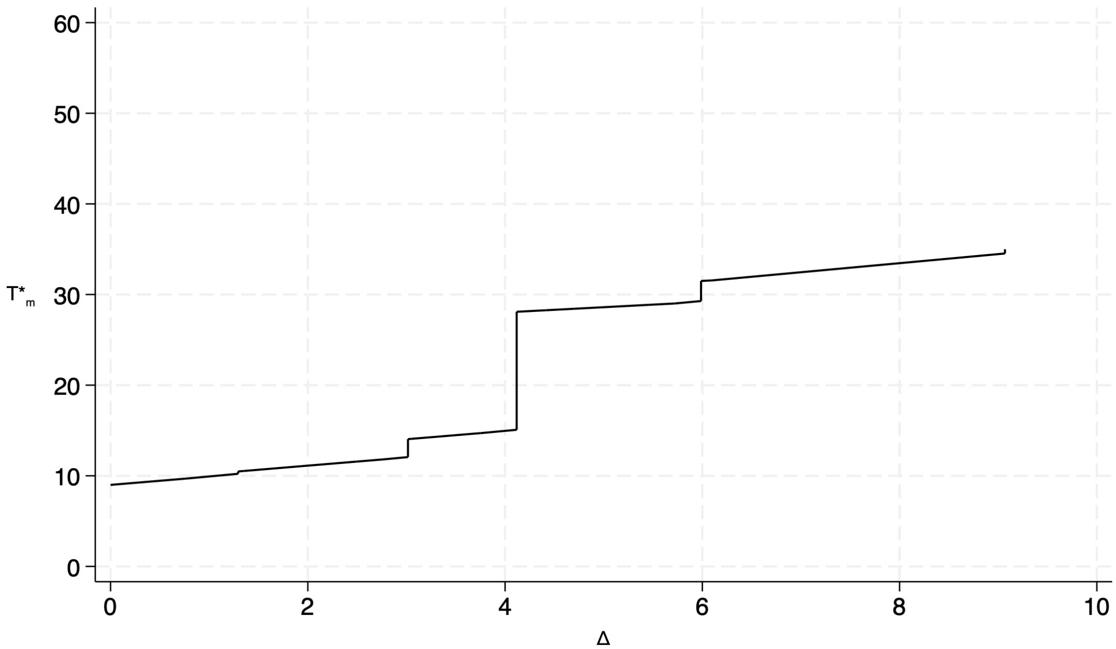
Appendix D.7

Figure D.7.a
Efficient Minimum Effective Tax Rates, Medium Strategic Complementarity, 35 Country Coalition, 2020



The figure presents minimum effective corporate tax rates that maximize GDP-weighted collective objectives of the 35-country coalition at different values of Δ in 2020. Tax rate strategic complementarity is assumed to be characterized by $\gamma = 0.4$ and $\lambda = 0.05$, which imply that $d\tau_i / d\overline{\tau} = 0.3$.

Figure D.7.b
Efficient Minimum Effective Tax Rates, Strong Strategic Complementarity, 35 Country Coalition, 2020



The figure presents minimum effective corporate tax rates that maximize GDP-weighted collective objectives of the 35-country coalition at different values of Δ in 2020. Tax rate strategic complementarity is assumed to be characterized by $\gamma = 1$ and $\lambda = 0.1$, which imply that $d\tau_i / d\overline{\tau} = 0.5$.

Appendix E

This appendix offers derivations of equations (22) and (23) in the text. Applying equations (18) and (21), it follows that

(E1) $$\sum \frac{\partial O_i}{\partial d_i} w_i = \left[\Delta - k + \lambda\left(\overline{\tau}_m - \tilde{\tau} - k\right)\right]\sum \theta_i w_i + \left(\lambda + \gamma\right)\left(\tau_m - \tilde{\tau}_B - k\right)\sum_B \theta_i w_i \ ,$$

in which $\tilde{\tau} \equiv \dfrac{\sum \tau_i \theta_i w_i}{\sum \theta_i w_i}$ is the average tax rate, weighted by $\theta_i w_i$. From the definition of $\overline{\tau}_m$,

(E2) $$\overline{\tau}_m = \sum \hat{\tau}_i \nu_i + \sum_B \left(\tau_m - \hat{\tau}_i\right)\nu_i ,$$

which implies that

(E3) $$\overline{\tau}_m = \overline{\tau} + k + \sum_B \left(\tau_m - \tau_i - k\right)\nu_i = \overline{\tau} + k + \left[\left(\tau_m - \tilde{\tau}_B - k\right) + \left(\tilde{\tau}_B - \overline{\tau}_B\right)\right]\psi \frac{\sum_B \theta_i w_i}{\sum \theta_i w_i} .$$

Consequently,

(E4) $$\left(\overline{\tau}_m - \tilde{\tau} - k\right) = \left(\overline{\tau} - \tilde{\tau}\right) + \left[\left(\tau_m - \tilde{\tau}_B - k\right) + \left(\tilde{\tau}_B - \overline{\tau}_B\right)\right]\psi \frac{\sum_B \theta_i w_i}{\sum \theta_i w_i} .$$

Together, (E1) and (E4) imply that

(E5) $$\sum \frac{\partial O_i}{\partial d_i} w_i = \left[\Delta - k + \lambda\left(\overline{\tau} - \tilde{\tau}\right)\right]\sum \theta_i w_i + \left[\left(\lambda\psi + \lambda + \gamma\right)\left(\tau_m - \tilde{\tau}_B - k\right) + \lambda\psi\left(\tilde{\tau}_B - \overline{\tau}_B\right)\right]\sum_B \theta_i w_i \ .$$

From equation (3), $M'\left(\tau\right) = 0$ requires that the product of the right side of (E5) and $\dfrac{d\overline{\tau}_m}{d\tau_m}$ equals the right side of (19), which is $\left(1 + 2\lambda + \gamma\right)\left(\tau_m - \tilde{\tau}_B - k\right)\sum_B \theta_i w_i$.

From (A6), $\frac{d\bar{\tau}_m}{d\tau_m}=\frac{\psi\sum_B\theta_i w_i/\sum\theta_i w_i}{\left[1-\left(1-\psi\sum_B\theta_i w_i/\sum\theta_i w_i\right)\frac{(\lambda+\gamma)}{(1+2\lambda+\gamma)}\right]}$. Solving for an efficient minimum tax rate τ_m^* by setting the product of $\psi\sum_B\theta_i w_i/\sum\theta_i w_i$ and the right side of (E5) equal to the product of $\left[1-\left(1-\psi\sum_B\theta_i w_i/\sum\theta_i w_i\right)\frac{(\lambda+\gamma)}{(1+2\lambda+\gamma)}\right]$ and the right side of (19),

(E6)
$$\begin{aligned}&\left[\Delta-k+\lambda(\bar{\tau}-\tilde{\tau})\right]\psi\sum_B\theta_i w_i+\left[(\lambda\psi+\lambda+\gamma)\left(\tau_m^*-\tilde{\tau}_B-k\right)+\lambda\psi\left(\tilde{\tau}_B-\bar{\tau}_B\right)\right]\psi\frac{\left(\sum_B\theta_i w_i\right)^2}{\sum\theta_i w_i}\\&=(1+2\lambda+\gamma)\left(\tau_m^*-\tilde{\tau}_B-k\right)\sum_B\theta_i w_i-\left[1-\psi\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\right](\lambda+\gamma)\left(\tau_m^*-\tilde{\tau}_B-k\right)\sum_B\theta_i w_i\end{aligned}.$$

Simplifying (E6),

(E7) $$\psi\left[\Delta-k+\lambda(\bar{\tau}-\tilde{\tau})\right]+\psi^2\lambda\left[\left(\tau_m^*-\tilde{\tau}_B-k\right)+\left(\tilde{\tau}_B-\bar{\tau}_B\right)\right]\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}=(1+\lambda)\left(\tau_m^*-\tilde{\tau}_B-k\right).$$

Recalling that $k=\left[\frac{\gamma+\lambda}{1+2\lambda+\gamma}\right](\bar{\tau}_M-\bar{\tau})$, it follows from (E3) that

(E8) $$k\frac{(1+2\lambda+\gamma)}{(\lambda+\gamma)}=k+\left[\left(\tau_m^*-\tilde{\tau}_B-k\right)+\left(\tilde{\tau}_B-\bar{\tau}_B\right)\right]\psi\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}.$$

Consequently,

(E9) $$k=\frac{(\lambda+\gamma)}{(1+\lambda)}\left[\left(\tau_m^*-\tilde{\tau}_B-k\right)+\left(\tilde{\tau}_B-\bar{\tau}_B\right)\right]\psi\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}.$$

Using (E9) to substitute for *k*, (E7) implies

(E10)
$$\psi\Delta+\psi\lambda\left(\bar{\tau}-\tilde{\tau}\right)-\left(\tilde{\tau}_B-\bar{\tau}_B\right)\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\psi^2\left[\frac{(\lambda+\gamma)}{(1+\lambda)}-\lambda\right]=$$
$$\left(\tau_m^*-\tilde{\tau}_B-k\right)\left[1+\lambda\left(1-\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\psi^2\right)+\frac{(\lambda+\gamma)}{(1+\lambda)}\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\psi^2\right].$$

Equation (22) in the text follows directly from (E10).

Equation (E9) implies that

(E11)
$$k=\frac{\frac{(\lambda+\gamma)}{(1+\lambda)}\left[\left(\tau_m^*-\tilde{\tau}_B\right)+\left(\tilde{\tau}_B-\bar{\tau}_B\right)\right]\psi\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}}{\left[1+\frac{(\lambda+\gamma)}{(1+\lambda)}\psi\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\right]}.$$

If $v_i=\theta_i w_i\big/\sum\theta_i w_i$, then $\psi=1$, $\bar{\tau}=\tilde{\tau}$ and $\tilde{\tau}_B=\bar{\tau}_B$. Applying these substitutions, (E10) and (E11) together imply

(E12)
$$\Delta=\frac{\left(\tau_m^*-\tilde{\tau}_B\right)}{\left[1+\frac{(\lambda+\gamma)}{(1+\lambda)}\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\right]}\left[1+\lambda\left(1-\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\right)+\frac{(\lambda+\gamma)}{(1+\lambda)}\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\right].$$

Equation (E12) implies that

(E13)
$$\tau_m^*-\tilde{\tau}_B=\frac{\Delta\left[1+\frac{(\lambda+\gamma)}{(1+\lambda)}\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\right]}{\left[1+\lambda\left(1-\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\right)+\frac{(\lambda+\gamma)}{(1+\lambda)}\frac{\sum_B\theta_i w_i}{\sum\theta_i w_i}\right]},$$

from which equation (23) in the text directly follows.

Appendix F

This appendix considers the impact of minimum taxes on weighted sums of country objectives in settings in which tax rates exhibit strategic reactions, as analyzed in section 6.

The tax rates of group *A* countries are unconstrained by the minimum tax rate, which impacts their objectives simply by changing the average world tax rate from $\overline{\tau}$, its value in the absence of a minimum tax, to $\overline{\tau}_m$. Applying the definition $k = \left[\frac{\gamma+\lambda}{1+2\lambda+\gamma}\right]\left(\overline{\tau}_m - \overline{\tau}\right)$ to equation (21) produces

$$\text{(F1)} \quad \frac{\partial O_i\left(\hat{\tau}_i, \hat{\tau}_i - \overline{\tau}_m\right)}{\partial d_i} = \theta_i\left[\tau_i^* - \tau_i\left(1+\lambda\right) + \overline{\tau}\left(1+\lambda\right)\left(\frac{\gamma+\lambda}{1+2\lambda+\gamma}\right) + \overline{\tau}_m\left(\lambda - \frac{\left(1+\lambda\right)\left(\gamma+\lambda\right)}{1+2\lambda+\gamma}\right)\right].$$

Since the envelope condition (1) implies that marginal endogenous changes in a country's chosen tax rate do not affect the degree to which it satisfies its objectives, the effect of a minimum tax regime on the objectives of an unconstrained group *A* country is

$$\text{(F2)} \quad -\int_{\overline{\tau}}^{\overline{\tau}_m} \frac{\partial O_i\left(\hat{\tau}_i, \hat{\tau}_i - z\right)}{\partial d_i} dz.$$

Interpreting $\overline{\tau}_m$ in (F1) as *z* in (F2), and evaluating the integral in (F2), it follows that the effect of a minimum tax on the objectives of a group *A* country is

$$\text{(F3)} \quad -\theta_i\left(\overline{\tau}_m - \overline{\tau}\right)\left[\tau_i^* - \tau_i\left(1+\lambda\right) + \overline{\tau}\left(1+\lambda\right)\left(\frac{\gamma+\lambda}{1+2\lambda+\gamma}\right)\right] + \theta_i\left(\frac{\overline{\tau}_m^2 - \overline{\tau}^2}{2}\right)\left(\lambda - \frac{\left(1+\lambda\right)\left(\gamma+\lambda\right)}{1+2\lambda+\gamma}\right).$$

Group *B* countries are likewise affected by increasing the average world tax rate from $\overline{\tau}$ to $\overline{\tau}_m$, and are also affected by the minimum tax requirement that they elevate their tax rates to τ_m. The group *B* experience of minimum taxation can be decomposed into

$$\text{(F4)} \quad \begin{aligned} & O_i\left(\tau_m, \tau_m - \overline{\tau}_m\right) - O_i\left(\tau_i, \tau_i - \overline{\tau}\right) = \\ & \left[O_i\left(\tau_m, \tau_m - \overline{\tau}_m\right) - O_i\left(\hat{\tau}_i, \hat{\tau}_i - \overline{\tau}_m\right)\right] + \left[O_i\left(\hat{\tau}_i, \hat{\tau}_i - \overline{\tau}_m\right) - O_i\left(\tau_i, \tau_i - \overline{\tau}\right)\right]. \end{aligned}$$

Equation (F3) captures the second bracketed term on the right side of (F4), reflecting that higher world average tax rates affect the desired tax rates of group *B* countries. Consequently, it is useful to take a weighted sum of (F3) over all countries, which produces

$$\text{(F5)} \qquad -\left\{\left(\overline{\tau}_m - \overline{\tau}\right)\left[\Delta - \tilde{\tau}\lambda + \overline{\tau}\frac{(1+\lambda)(\gamma+\lambda)}{(1+2\lambda+\gamma)}\right] + \left(\frac{\overline{\tau}_m^2 - \overline{\tau}^2}{2}\right)\left(\lambda - \frac{(1+\lambda)(\gamma+\lambda)}{(1+2\lambda+\gamma)}\right)\right\}\sum \theta_i w_i \text{ .}$$

Simplifying this expression, and applying that $\left(\overline{\tau}_m - \overline{\tau}\right) = \left(\tau_m - \overline{\tau}_B\right)\psi \frac{\sum_B \theta_i w_i}{\sum \theta_i w_i}$, yields

$$\text{(F6)} \qquad -\left(\tau_m - \overline{\tau}_B\right)\psi\left[\Delta - \left(\tilde{\tau} - \overline{\tau}\right)\lambda + \left(\frac{\overline{\tau}_m - \overline{\tau}}{2}\right)\frac{\left(\lambda^2 - \gamma\right)}{(1+2\lambda+\gamma)}\right]\sum_B \theta_i w_i \text{ .}$$

The first bracketed term on the right side of (F4) can be cast as

$$\text{(F7)} \qquad \int_{\tau_i+k}^{\tau_m} \frac{\partial O_i\left(z, z-\overline{\tau}_m\right)}{\partial \tau_i} dz + \int_{\tau_i+k}^{\tau_m} \frac{\partial O_i\left(z, z-\overline{\tau}_m\right)}{\partial d_i} dz \text{ .}$$

Applying (17), (18), and (1) to evaluate (F7), it follows that this component of the impact of minimum taxation on the objectives of a group *B* country is

$$\text{(F8)} \qquad \theta_i\left(1+2\lambda+\gamma\right)\int_{\tau_i+k}^{\tau_m}\left(z - \tau_i - k\right)dz \text{ .}$$

Evaluating the integral in (F8) produces

$$\text{(F9)} \qquad \theta_i\left(1+2\lambda+\gamma\right)\left[\frac{\tau_m^2 - \left(\tau_i + k\right)^2}{2} - \left(\tau_m - \left(\tau_i + k\right)\right)\left(\tau_i + k\right)\right].$$

Taking a weighted sum of (F9) over all group *B* countries yields

$$\text{(F10)} \qquad \left(1+2\lambda+\gamma\right)\left[\frac{\left(\tau_m - k\right)^2}{2} - \tilde{\tau}_B\left(\tau_m - k\right) + \frac{\sum_B \tau_i^2 \theta_i w_i}{2\sum_B \theta_i w_i}\right]\sum_B \theta_i w_i \text{ .}$$

Further simplifying, and applying the definition $\sigma_B^2 \equiv \dfrac{\sum_B (\tau_i - \tilde{\tau}_B)^2 \theta_i w_i}{\sum_B \theta_i w_i}$, (F10) becomes

(F11)
$$\frac{1}{2}(1+2\lambda+\gamma)\left[(\tau_m - \tilde{\tau}_B - k)^2 + \sigma_B^2\right]\sum_B \theta_i w_i .$$

The effect of a minimum tax on the weighted sum of country objectives, $M(\tau_m) - S$, equals the sum of (F6) and (F11). Consequently,

(F12)
$$\frac{M(\tau_m)-S}{\frac{-1}{2}\sum \theta_i w_i} = \left\{ \begin{array}{l} (\tau_m - \overline{\tau}_B)\psi\left[2\Delta - 2(\tilde{\tau} - \overline{\tau})\lambda + \dfrac{(\overline{\tau}_m - \overline{\tau})(\lambda^2 - \gamma)}{(1+2\lambda+\gamma)}\right] \\ -(1+2\lambda+\gamma)\left[(\tau_m - \tilde{\tau}_B - k)^2 + \sigma_B^2\right] \end{array} \right\} \frac{\sum_B \theta_i w_i}{\sum \theta_i w_i} .$$

An objective-maximizing choice of τ_m maximizes the right side of (F12), which can therefore be used to compare alternative values of τ_m^* that satisfy the first-order condition (22).