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EVALUATING TAX HARMONIZATION

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ABSTRACT

Tax harmonization entails a uniform rate that may not suit all governments. Harmonization can advance collective governmental objectives only if the standard deviation of tax rates is less than the average downward effect of tax competition on rates. Since an efficient harmonized tax rate undoes the effect of competition, an efficient rate equals or exceeds the sum of the observed average tax rate and the standard deviation of rates. In 2020, the mean world corporate tax rate was 25.9%, and the standard deviation 4.5%, so if there is an efficient harmonized world tax rate, it must be 30.4% or higher.

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1. Introduction.

Tax harmonization is an appealing alternative to tax competition. In a perfectly harmonized system, there is no competition, because there is no independent choice. Instead of a tax landscape strewn with widely differing rates and bases, a harmonized system features a single tax rate applied to a common base. Since tax rates do not differ, there are no tax-based reasons to prefer locating economic activity in one jurisdiction over another. And a harmonized rate can be chosen without concern that it might possibly be undercut by members of the coalition, thereby affording a range of tax possibilities that would not otherwise be available.

In the absence of tax harmonization or other forms of international coordination, governments are free to choose whatever tax rates and bases best advance their own objectives. Their tax choices commonly differ, reflecting differences in economic conditions and political preferences. For example, countries with underperforming economies might offer lower business taxes in efforts to attract greater business activity, whereas those seeking revenue to finance large government expenditures will be inclined to impose higher taxes. Furthermore, countries differ in the extent to which their choices are influenced by international competition. As a result of these and other considerations, there is significant variation in the tax rates that countries choose.

Tax harmonization can relieve downward rate pressure from tax competition, but does so at the cost of requiring governments to adhere to collective rules that may be insensitive to differences in the needs of individual jurisdictions. A harmonized tax can be set as high as countries collectively desire, making it possible to reverse any effects of tax competition on average tax rates. Consequently, the larger are the effects of tax competition, the greater is the potential corrective opportunity presented by tax harmonization. Notably, however, tax harmonization does more than just adjust the average tax rate. Since a harmonized tax rate is the same for all, tax harmonization prevents countries from tailoring their tax rates to individual situations. The cost of mandatory uniformity rises with differences in desired tax rates; and these differences are reflected in, and largely revealed by, differences in the tax rates that countries choose in the absence of harmonization.

The purpose of this paper is to use observed tax choices to evaluate the properties of tax harmonization alternatives. A second-order Taylor approximation yields the simple rule that tax rate harmonization advances collective government objectives only if tax competition reduces tax rates by more than the standard deviation of observed tax rates. This rule captures the reality that the diversity of economic and political considerations that determine tax rates in the absence of coordination makes it impossible for a single harmonized tax rate to conform to every government's desired tax policy – and the standard deviation measure reflects the second order nature of the cost of deviating from preferred tax rates. Given the multiplicity of preferred tax rates, costs of deviating from preferred rates, and perceived costs of tax competition, it is striking that the criterion for objective-enhancing tax harmonization takes the form of a simple standard deviation.

The standard deviation rule emerges from comparing uncoordinated taxation to efficient tax harmonization. The efficient harmonized rate is itself the sum of the average observed tax rate and the average amount by which tax competition depresses rates. Since tax harmonization maximizes collective objectives only if tax competition reduces tax rates by more than their observed standard deviation, it follows that an efficient harmonized tax rate must equal or exceed the average observed tax rate plus the standard deviation of observed tax rates. In 2020, the world's mean corporate tax rate weighted by GDP was 25.9%, and the standard deviation 4.5%, so if there is an objective-maximizing harmonized corporate tax, its rate must lie at or above 30.4%.

Choosing an efficient harmonized tax rate requires a precise estimate of the effect of tax competition on observed tax rates. Even in the absence of such knowledge, it is possible to use observational data to inform the choice of harmonized rates. If governments do not know the effect of tax competition, are nonetheless committed to harmonizing their tax rates, and ask only what rate to choose, it follows from the second-order approximation that a harmonized rate equal to the average observed tax rate plus the standard deviation of observed tax rates maximizes the probability that harmonization advances collective objectives. In the international context in 2020, this application of the standard deviation rule implies that 30.4% is more likely than any other harmonized tax rate to advance the objectives of governments around the world. While governments may or may not be tempted to select a harmonized tax rate on this basis, it is nonetheless useful to know that a rate equal to 30.4% has this property.

2. Tax Harmonization and Government Objectives.

This section considers a setting in which each country's government chooses its corporate tax rate while balancing economic and political considerations that include not only the economic costs of different taxes, and desired distribution of tax burdens, but also competition with other governments. These economic and political preferences can be captured by a function of a country *i*'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 $\overline{\tau} = \sum \tau_i v_i$, with $\sum v_i = 1$. The weights used to construct $\overline{\tau}$ reflect the relative importance of the tax rates of different countries, which might for example be proportional to GDP or other measures of the volume of taxed activities. 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.[1] For analytical convenience, $O_i\left(\tau_i, d_i\right)$ is taken to be continuous and twice continuously differentiable in its arguments, with higher values of $O_i\left(\tau_i, d_i\right)$ corresponding to greater satisfaction of government objectives.

2.1. An approximation.

It is useful to consider the tax rate that maximizes country *i*'s objectives in the absence of international tax differences, and to denote this tax rate by τ_i^*. The tax rate 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 that all other countries would follow exactly. In this sense, τ_i^* is the tax rate that country *i* would choose in the absence of international competition, and reflects domestic

[1] Sections 3.5 and 3.6 consider generalizations of this specification.

considerations such as desire for economic development, preferences over the distribution of tax burdens, and government revenue needs.

In practice, most countries do not impose tax rates that they would select in the absence of international competition; and tax rates certainly differ. Country *i*'s objective level $O_i\left(\tau_i, d_i\right)$ can be evaluated using a Taylor expansion around $O_i\left(\tau_i^*, 0\right)$, the second-order approximation of which is

(1)

$$O_i\left(\tau_i, d_i\right) = O_i\left(\tau_i^*, 0\right) + \left(\tau_i - \tau_i^*\right)\gamma_{0i} - \left(\tau_i - \tau_i^*\right)^2 \gamma_{1i} - \left(\tau_i - \overline{\tau}\right)\gamma_{2i} - \left(\tau_i - \overline{\tau}\right)^2 \gamma_{3i} - \left(\tau_i - \tau_i^*\right)\left(\tau_i - \overline{\tau}\right)\gamma_{4i},$$

with $\gamma_{0i} = \frac{\partial O_i\left(\tau_i^*, 0\right)}{\partial \tau_i}$, $\gamma_{1i} = \frac{-1}{2}\frac{\partial^2 O_i\left(\tau_i^*, 0\right)}{\partial \tau_i^2}$, $\gamma_{2i} = \frac{-\partial O_i\left(\tau_i^*, 0\right)}{\partial d_i}$, $\gamma_{3i} = \frac{-1}{2}\frac{\partial^2 O_i\left(\tau_i^*, 0\right)}{\partial d_i^2}$, and

$\gamma_{4i} = \frac{-\partial^2 O_i\left(\tau_i^*, 0\right)}{\partial \tau_i \partial d_i}$.

Since τ_i^* is the objective-maximizing tax rate in the absence of tax differences, it follows that $\frac{\partial O_i\left(\tau_i^*, 0\right)}{\partial \tau_i} = \gamma_{0i} = 0$; and since τ_i^* corresponds to a maximum it must be the case that $\frac{-1}{2}\frac{\partial^2 O_i\left(\tau_i^*, 0\right)}{\partial \tau_i^2} = \gamma_{1i} > 0$. The sign of γ_{2i} depends on how country *i* evaluates differences in world average tax rates, holding its own tax rate constant. If, as is commonly assumed to be the case in models of tax competition, a country feels that it is costly to have a tax rate exceeding the world average, and beneficial to have one below the world average, then $\gamma_{2i} > 0$. Alternatively, a country may feel that it benefits from the opportunities created by lower foreign tax rates, and is hurt by higher foreign taxes, in which case $\gamma_{2i} < 0$; and the sign of γ_{2i} may differ between countries. Similarly, models of tax competition commonly assume that there are convex costs of deviating from world average tax rates, which implies that $\gamma_{3i} > 0$; but it is also entirely possible that $\gamma_{3i} < 0$, particularly for countries with lower than average tax rates. Tax competition theory currently has little to say about the sign or magnitude of γ_{4i}. It is reasonable to expect the parameters γ_{1i}, γ_{2i}, γ_{3i}, and γ_{4i} all to be positive, though with declining certainty: it is clear that $\gamma_{1i} > 0$, and likely that $\gamma_{2i} > 0$, whereas the signs of γ_{3i} and γ_{4i} are less certain.

The second-order Taylor expansion in (1) approximates a country's objectives. This focuses the analysis in a way that facilitates drawing useful inferences, but does so at the cost of restricting the validity of the findings to settings in which the second-order approximation does not mislead. In many cases the first- and second-order terms in (1) will capture the salient features of tax rate differences; and there is little if any empirical evidence that third- and higher-order terms significantly influence country objectives or tax rate determination.

2.2. Independent tax rate choice.

If countries choose tax rates that advance their own objectives, and equation (1) accurately represents these objectives, then it should be the case that their tax rates maximize (1). Taking this to be the case,[2] and assuming that countries ignore their own effects on the world average tax rate, it follows that a country perceives the effect of a small change in its own tax rate to be

(2) $$2\gamma_{1i}\left(\tau_i^* - \tau_i\right) - \gamma_{2i} + 2\gamma_{3i}\left(\overline{\tau} - \tau_i\right) + \gamma_{4i}\left(\overline{\tau} + \tau_i^* - 2\tau_i\right).$$

Setting (2) equal to zero yields the implied objective-maximizing tax rate

(3) $$\tau_i = \frac{\left(\gamma_{1i} + \frac{\gamma_{4i}}{2}\right)\tau_i^* + \left(\gamma_{3i} + \frac{\gamma_{4i}}{2}\right)\overline{\tau}}{\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right)} - \frac{\frac{\gamma_{2i}}{2}}{\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right)},$$

which corresponds to a maximum only if

[2] While the linearity of differentiation implies that the derivative of a function equals the derivative of its Taylor expansion, there are circumstances in which a second-order Taylor expansion closely approximates the value of a function without the derivative of the second-order expansion closely approximating the function's derivative. The derivation of (3) assumes that restricting attention to the first- and second-order expansion terms produces valid approximations not only of the value of the $O_i\left(\tau_i, d_i\right)$ function but also of its derivative.

(4) $$\frac{\partial^2 O_i\left(\tau_i, d_i\right)}{\partial \tau_i^2} + \frac{\partial^2 O_i\left(\tau_i, d_i\right)}{\partial d_i^2} + 2\frac{\partial^2 O_i\left(\tau_i, d_i\right)}{\partial \tau_i \partial d_i} = -2\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right) < 0 .$$

The expression of a country's desired tax rate in equation (3) takes an intuitive form. The first term on the right side is a weighted average of τ_i^*, country *i*'s desired tax rate in the absence of competition, and $\bar{\tau}$, the world average tax rate. The second-order condition (4) guarantees that the common denominator of the terms on the right side of (3) are positive, so the second term on the right side of (3) implies that a greater value of γ_{2i} reduces country *i*'s tax rate. The strategic element of tax setting takes the form $\frac{\partial \tau_i}{\partial \bar{\tau}} = \frac{\gamma_{3i} + \frac{\gamma_{4i}}{2}}{\gamma_{1i} + \gamma_{3i} + \gamma_{4i}}$: a positive value of $\left(\gamma_{3i} + \frac{\gamma_{4i}}{2}\right)$ implies that tax rates are strategic complements, with $\frac{\partial \tau_i}{\partial \bar{\tau}} > 0$, whereas a negative value implies that tax rates are strategic substitutes. While strategic complementarity – a country reacting to tax cuts elsewhere by reducing its own tax rate – is a common feature of tax competition models, complementarity is far from guaranteed to prevail, and indeed there are important cases in which tax rates will be strategic substitutes. And notably, a cost of having a tax rate that exceeds the world average implies that $\gamma_{2i} > 0$, which depresses the tax rate that a country will choose even in the absence of strategic complementarity or substitutability.

2.3. Aggregate objective satisfaction.

One consequence of country differences in preferred tax rates and perceived costs of deviating from the world average tax rate is that any harmonization effort is apt to further the objectives of some while thwarting the objectives of others. An overall assessment of the consistency of tax harmonization with national objectives therefore requires a method of aggregating outcome assessments from the standpoint of national governments. If tax rate preferences are embedded in broader objective functions $F_i\left[O_i\left(\tau_i, d_i\right) + y_i\right]$, with y_i a transferable commodity such as money, then $O_i\left(\tau_i, d_i\right)$ can be interpreted as willingness to pay for tax outcomes. With accompanying transfers of *y*, tax harmonization that increases the sum of $O_i\left(\tau_i, d_i\right)$ 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 relative importance of advancing the objectives of different governments. Denoting this weighted sum by *S*, it follows that

$$S = \sum O_i\left(\tau_i, d_i\right) w_i \,, \tag{5}$$

with $\sum w_i = 1$, and $w_i = 1/n$ if transfers of *y* are used to offset the distributional effects of collective tax measures.

In evaluating (5), it is helpful to define Δ as the effect of tax competition on tax rates, the difference between average tax rates chosen without regard to competition and average tax rates chosen in practice,

$$\Delta \equiv \frac{\sum\left(\tau_i^* - \tau_i\right)\gamma_{1i} w_i}{\sum \gamma_{1i} w_i}, \tag{6}$$

with weights given by $\gamma_{1i} w_i$. The calculations of Appendix A show that the definition of Δ in (6), together with the formula in (3) and the aggregation rule in (5), implies that, in the absence of harmonization,

$$\begin{aligned} S = {} & \sum O_i\left(\tau_i^*, 0\right) w_i - \sum \tau_i^{*2} \gamma_{1i} w_i + \sum\left(\tau_i - \bar{\tau}\right)^2 \left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right) w_i \\ & - \bar{\tau}^2 \sum \gamma_{1i} w_i + 2\bar{\tau} \sum \tau_i \gamma_{1i} w_i + 2\Delta\bar{\tau} \sum \gamma_{1i} w_i \end{aligned}. \tag{7}$$

2.4. Efficient tax harmonization.

An important alternative to independent tax setting is for all countries to harmonize their taxes at a common rate. Harmonized taxes at rate τ_h yield aggregate objective satisfaction $R\left(\tau_h\right) \equiv \sum O_i\left(\tau_h, 0\right) w_i$, so equation (1) implies that

$$R\left(\tau_h\right) = \sum O_i\left(\tau_i^*, 0\right) w_i - \sum\left(\tau_i^* - \tau_h\right)^2 \gamma_{1i} w_i \,. \tag{8}$$

Defining $\tilde{\tau} \equiv \frac{\sum \tau_i \gamma_{1i} w_i}{\sum \gamma_{1i} w_i}$ to be the average tax rate calculated using weights $\gamma_{1i} w_i$, it follows that $\frac{\sum \tau_i^* \gamma_{1i} w_i}{\sum \gamma_{1i} w_i} = \tilde{\tau} + \Delta$, and (8) implies that

(9) $$R\left(\tau_h\right) = \sum O_i\left(\tau_i^*, 0\right) w_i - \sum \tau_i^{*2} \gamma_{1i} w_i + 2\tau_h\left(\tilde{\tau} + \Delta\right) \sum \gamma_{1i} w_i - \tau_h^2 \sum \gamma_{1i} w_i \ .$$

Together, (7) and (9) imply that

(10) $$\frac{R\left(\tau_h\right) - S}{\sum \gamma_{1i} w_i} = 2\tau_h\left(\tilde{\tau} + \Delta\right) - \tau_h^2 - \sum \left(\tau_i - \overline{\tau}\right)^2 \frac{\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right) w_i}{\sum \gamma_{1i} w_i} + \overline{\tau}^2 - 2\overline{\tau}\left(\tilde{\tau} + \Delta\right).$$

Since $\sum \gamma_{1i} w_i > 0$, tax harmonization at rate τ_h improves aggregate objective satisfaction if the right side of equation (10) is positive, whereas harmonization reduces aggregate objective satisfaction if the right side is negative.

What if governments choose an efficient harmonized rate? It is evident from differentiating the right side of (9) with respect to τ_h that the value τ_h^* that maximizes $R\left(\tau_h\right)$ is given by

(11) $$\tau_h^* = \tilde{\tau} + \Delta = \frac{\sum \tau_i^* \gamma_{1i} w_i}{\sum \gamma_{1i} w_i}.$$

Equation (11) quite reasonably implies that the aggregate objective-maximizing harmonized tax rate is the weighted average of the tax rates that maximize individual country objectives in the absence of competition. If governments adopt τ_h^* in harmonizing their tax rates, then (10) implies

(12) $$\frac{R\left(\tau_h^*\right) - S}{\sum \gamma_{1i} w_i} = \left(\Delta + \tilde{\tau} - \overline{\tau}\right)^2 - \sum \left(\tau_i - \overline{\tau}\right)^2 \frac{\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right) w_i}{\sum \gamma_{1i} w_i}.$$

It follows from (12) that

(13) $$\frac{R\left(\tau_h^*\right)-S}{\sum\gamma_{1i}w_i}=\Delta^2-\sigma^2-\sum\left(\tau_i-\overline{\tau}\right)^2\frac{\left(\gamma_{3i}+\gamma_{4i}\right)w_i}{\sum\gamma_{1i}w_i}-2\Delta\left(\overline{\tau}-\tilde{\tau}\right),$$

in which $\sigma^2\equiv\sum\left(\tau_i-\tilde{\tau}\right)^2\frac{\gamma_{1i}w_i}{\sum\gamma_{1i}w_i}$ is the weighted variance of τ_i.

3. The Standard Deviation Rule.

Efficient tax harmonization advances collective objectives if and only if the right side of (13) is positive. The first term on the right side of (13) is the square of the effect of tax competition on average tax rates, and the second term is the weighted variance of τ_i. If $\gamma_{3i}=\gamma_{4i}=0$, so there is no strategic interaction in tax setting, and $v_i=\frac{\gamma_{1i}w_i}{\sum\gamma_{1i}w_i}$, which makes the tax rate average $\tilde{\tau}$ calculated using objective-related weights $\gamma_{1i}w_i$ equal to the tax rate average $\overline{\tau}$ relevant for country comparisons, then the third and fourth terms are both zero, and (13) is positive if the weighted variance of observed tax rates is less than the squared effect of tax competition on rates. Expressed differently, tax harmonization advances collective objectives if and only if tax competition reduces average tax rates by more than the standard deviation of observed tax rates.

The standard deviation rule captures important aspects of the impact of tax harmonization. Tax harmonization is costly from the standpoint of achieving the objectives of governments with preferred tax rates that differ from the harmonized rate. The aggregate cost of tax harmonization depends on the distribution of τ_i^*, which is unknown, though reflected in the distribution of observed tax rates – and that is why the variance term appears in (13). It remains the case that the effect of harmonization also depends on the values of γ_{1i}, γ_{2i}, γ_{3i}, and γ_{4i}, which are likewise unknown, though their impact is summarized by the terms in (13).

3.1. Interpreting the rule.

How can it be that the rule for efficient tax harmonization takes as simple a form as (13)? The analysis relies on a second-order Taylor approximation, and the standard deviation is a second-order statistic; but the standard deviation is just one in a very large class of second-order statistics. Furthermore, any affine transformation of the standard deviation is also a second-order statistic, yet what matters for evaluating tax harmonization in the absence of strategic interactions is the standard deviation itself, and not a transformation.

The standard deviation rule can be interpreted as comparing the effect of replacing independently chosen taxes and efficiently harmonized taxes with a third, and less appealing, alternative, which is taxes harmonized at rate $\bar{\tau}$. Figure 1 depicts this comparison. Independently chosen taxes maximize each government's objective subject to facing the world average tax rate of $\bar{\tau}$. Since harmonizing all taxes at $\bar{\tau}$ leaves the average tax rate unchanged, this alternative must therefore reduce collective objectives. Similarly, one reduces collective objectives by replacing taxes harmonized at the efficient rate τ_h^* with taxes harmonized at rate $\bar{\tau}$. A comparison of the losses associated with these moves reveals whether independent tax setting or efficient harmonization produces greater satisfaction of collective objectives.

Starting from independent tax setting, harmonizing all taxes at $\bar{\tau}$ does not change the average tax rate, so the impact on country *i* objective satisfaction is given by the integral of (2) over the range from τ_i to $\bar{\tau}$. If τ_i is an optimizing choice, then the derivative of country *i*'s objective level with respect to τ_i is zero in the neighborhood of τ_i, though from (4) the relevant second derivative is nonzero and given by $-2\left(\gamma_{1i}+\gamma_{3i}+\gamma_{4i}\right)$. Since this second derivative is unchanging, it follows that the effect on country *i* objectives of replacing τ_i with $\bar{\tau}$ is given by $\left(\frac{1}{2}\right)(-2)\left(\gamma_{1i}+\gamma_{3i}+\gamma_{4i}\right)\left(\bar{\tau}-\tau_i\right)^2$, as in the Harberger triangle and analogous second order approximations to deadweight loss.[3] The weighted sum of these effects is a variance, and appears as the second term on the right side of (12).

[3] Harberger (1964, 1971); Auerbach (1985); Hines (1999).

Replacing efficient harmonization with uniform taxes at rate $\overline{\tau}$ also reduces aggregate objective satisfaction. Since the efficient harmonized rate τ_h^* maximizes aggregate objectives given by (8), the derivative with respect to τ_h is zero at τ_h^*, but the second derivative is $-2\sum \gamma_{1i} w_i$. It follows that the effect on aggregate objectives of reducing the harmonized tax rate from τ_h^* to $\overline{\tau}$ equals $\frac{1}{2}\left(-2\sum \gamma_{1i} w_i\right)\left(\overline{\tau} - \tau_h^*\right)^2$. Replacing τ_h^* with $\left(\Delta + \tilde{\tau}\right)$, this implies that the effect of reducing the harmonized rate from τ_h^* to $\overline{\tau}$ is given by $-\left(\Delta + \tilde{\tau} - \overline{\tau}\right)^2 \sum \gamma_{1i} w_i$, which is the first squared term on the right side of (12).

If competitive tax reductions impact outcomes, then neither tax harmonization nor independent tax setting maximizes collective objectives, except in very special cases. Tax harmonization is insufficiently sensitive to individual country preferences; and individual tax choice fails to incorporate effects on others. This is clear for small potential changes: starting from tax rates harmonized at τ_h^*, there is scope to increase aggregate objective satisfaction by increasing some tax rates and reducing others while leaving the average unchanged. Appendix B considers the properties of tax rates that maximize (5). These taxes correspond neither to (11), which characterizes efficient tax harmonization, nor to (3), which characterizes individual tax rate choice. Tax rates that maximize (5) are differentiated, and are either all higher or all lower than the tax rates that countries choose independently.

3.2. Modifications to the simple rule.

Nonzero values of γ_{3i} or γ_{4i} modify the implications of (13). The third term on the right side of (13) is the interaction between squared deviations from mean tax rates and the γ_{3i} and γ_{4i} terms that appear in strategic interactions. If the γ_{3i} and γ_{4i} terms are positive, so that tax rates are strategic complements, then since the squared deviations that appear in (13) are also necessarily positive, it follows that Δ must exceed the standard deviation of tax rates in order for (13) to be positive. If instead the γ_{3i} and γ_{4i} terms are negative, so tax rates are strategic substitutes, then (13) implies that there are lower costs of tax harmonization for any given observed tax rate variance.

In analyzing the potential implications of strategic tax setting, it is convenient to express the values of γ_{3i} and γ_{4i} as

(14a) $$\gamma_{3i} = \gamma_{1i}\left(\gamma_3 + \hat{\gamma}_{3i}\right)$$

(14b) $$\gamma_{4i} = \gamma_{1i}\left(\gamma_4 + \hat{\gamma}_{4i}\right),$$

with γ_3 and γ_4 chosen so that $\hat{\gamma}_{3i}$ and $\hat{\gamma}_{4i}$ have zero means over the whole population. Then (13) becomes

(15) $$\frac{R\left(\tau_h^*\right)-S}{\sum \gamma_{1i} w_i} = \Delta^2 - \left(1+\gamma_3+\gamma_4\right)\left(\sigma^2+\xi\right) - \left(\gamma_3+\gamma_4\right)\left(\overline{\tau}-\tilde{\tau}\right)^2 - 2\Delta\left(\overline{\tau}-\tilde{\tau}\right),$$

with

(16) $$\xi \equiv \frac{\sum\left(\tau_i - \overline{\tau}\right)^2\left(\hat{\gamma}_{3i}+\hat{\gamma}_{4i}\right)\frac{\gamma_{1i} w_i}{\sum \gamma_{1i} w_i}}{1+\gamma_3+\gamma_4}.$$

The variable ξ is a covariance that is apt to be small in magnitude if there is little systematic difference between the average strategic tax-setting reactions of high- and low-tax countries. If $\xi = 0$ and $\overline{\tau} = \tilde{\tau}$, then (15) implies that harmonization advances collective objectives if and only if tax competition reduces average tax rates by more than the product of the standard deviation of observed tax rates and $\sqrt{1+\gamma_3+\gamma_4}$. It follows that, if $\left(\gamma_3+\gamma_4\right) \geq 0$, the effect of tax competition on average tax rates must equal or exceed the standard deviation of observed tax rates in order for harmonization to advance collective objectives. Under what circumstances will it be the case that $\left(\gamma_3+\gamma_4\right) \geq 0$? – as noted in Appendix C, $\left(\gamma_3+\gamma_4\right) > 0$ generally corresponds to cases in which tax rates are strategic complements, whereas if $\left(\gamma_3+\gamma_4\right) < 0$, then tax rates are typically strategic substitutes.

Any differences between mean tax rates calculated using v_i, the weight attached to country *i*'s tax rate in constructing a world average for comparison purposes, and $\frac{\gamma_{1i} w_i}{\sum \gamma_{1i} w_i}$, the collective assessment weight attached to deviations of country *i*'s tax rate from its preferred rate, also influence the implications of (13). This is evident from solving (15) for values of Δ for which $R(\tau_h^*) - S = 0$. Applying the quadratic formula to (15), any solution $\tilde{\Delta}$ must satisfy

$$\tilde{\Delta} = (\bar{\tau} - \tilde{\tau}) \pm \sqrt{1 + \gamma_3 + \gamma_4} \sqrt{\sigma^2 + \xi + (\bar{\tau} - \tilde{\tau})^2}, \tag{17}$$

so the critical value of Δ is potentially affected by differences between $\bar{\tau}$ and $\tilde{\tau}$.

3.3. Partial harmonization.

The model of section 2 considers the implications of universal tax harmonization. Alternatively, a subset of countries, such as the members of the European Union, might contemplate harmonizing its taxes, with the rest of the world remaining free to set taxes at will. From the standpoint of the objectives of the harmonizing coalition, the form and content of the prior analysis continues to apply, with $\tilde{\tau}$ and $\bar{\tau}$ now interpreted as average tax rates of the harmonizing group, and Δ the effect of group member tax competition on their average tax rate. Parameter values, however, are context-specific. For example, τ_i^* becomes the tax rate that country *i* would choose if it knew that every other country in the harmonizing group would have the same rate. Since harmonization within a coalition has less impact on the world average tax rate than does a universal alternative, values of τ_i^* are typically lower than they would be with global harmonization, producing a smaller Δ and a resulting reduced likelihood that harmonization satisfies (13). Partial harmonization imposes a cost of enforced uniformity while delivering in return muted benefits of higher average tax rates. Consequently, partial harmonization is most likely to advance group objectives in settings where group members constitute a very large portion of the world or would otherwise choose very similar tax rates.

3.4. Imprecise measurement and harmonization at an inefficient rate.

The standard deviation rule in (13) relies on governments imposing the objective-maximizing harmonized tax rate τ_h^* described by (11). Adoption of τ_h^* as a harmonized rate requires exact knowledge of aggregate desired tax rates in the absence of competition, or equivalently Δ, the effect of tax competition on aggregate tax rates. To the extent that there is uncertainty over the value of Δ, tax harmonization is apt to produce an outcome that is less consistent with collective objectives than appears in equation (13). For example, if instead of adopting τ_h^* as the harmonized rate, governments instead were to adopt $\tau_h^* + \varepsilon_h$, then as shown in Appendix D.1, the effect is to replace Δ^2 in (13) with $\left(\Delta^2 - \varepsilon_h^2\right)$. Even unbiased estimates of Δ that are used to determine τ_h^* will have positive expected values of ε_h^2, thereby reducing expected objective levels under tax harmonization and requiring downward adjustments to Δ^2 in applying (13).

Application of the standard deviation rule of equation (13) also relies on accurate estimates of σ^2, the variance of tax rates. As noted in Appendix D.2, unbiased measurement error in tax rates produces σ^2 estimates that exceed true values by the expected value of squared measurement error. Denoting this expectation by u^2, it follows that the true variance is the difference between σ^2, the measured variance, and u^2. Combining tax rate measurement error with imprecision in setting the harmonized rate therefore adds $\left(u^2 - \varepsilon_h^2\right)$ to the right side of (13), and adds the same term to the second square root term on the right side of (17). If tax rates are measured less precisely than harmonized tax rates are set, then (13) and (17) understate the likelihood that tax harmonization advances collective objectives, whereas if tax rates are measured more precisely than harmonized tax rates are set, then (13) and (17) overstate it.

3.5. Idiosyncratic tax comparisons.

The model presented in section 2 specifies country *i*'s objective as $O_i\left(\tau_i, d_i\right)$, with $d_i = \tau_i - \overline{\tau}$, thereby imposing that countries compare their tax rates to a (common) world average. Alternatively, countries might compare their own taxes to world averages that are specific to them, effectively replacing $O_i\left(\tau_i, d_i\right)$ with $O_i\left(\tau_i, d_i^{\rho}\right)$, with $d_i^{\rho} = \tau_i - \overline{\tau}_i$ and $\overline{\tau}_i = \sum_j \nu_j^i \tau_j$. In this specification, each country *i* uses its own idiosyncratic weights ν_j^i to construct a world average tax rate for comparison purposes, with $\sum_j \nu_j^i = 1, \forall i$. Appendix E considers the consequences of this adjustment, producing a condition that closely corresponds to equation (15), suggesting that this modification does not significantly alter the implications of the preceding analysis. The use of idiosyncratic weights to construct world average tax rates does not change the second-order considerations underlying the effect of tax harmonization on government objectives; and it does not affect $R\left(\tau_h^*\right)$. As noted in Appendix E, to the extent that tax rates are strategic complements, idiosyncratic weights that are uncorrelated with other preference parameters introduces a randomness that reduces *S*, and thereby somewhat broadens the range of cases in which harmonization would advance collective objectives.

3.6. Bilateral tax comparisons.

The specification of a country's objective as $O_i\left(\tau_i, d_i\right)$ imposes that the relevant feature of the tax rates of other countries is their weighted average. While this is a standard formulation in tax competition models,[4] it is possible that countries instead care about pairwise comparisons of their tax rates to those of others, which requires considering $O_i\left(\tau_i, \mathbf{d_i}\right)$, with $\mathbf{d_i}$ a vector of differences between country *i*'s tax rate and those of every other country. Given the large number of countries in the world, a second-order Taylor approximation to an objective function that incorporates pairwise comparisons would have thousands of unobserved parameters, rendering it largely infeasible to analyze. A restricted version of this model is given by

(18)
$$\begin{aligned} O_i\left(\tau_i, \mathbf{d_i}\right) = O_i\left(\tau_i^*, \mathbf{0}\right) - \left(\tau_i - \tau_i^*\right)^2 \gamma_{1i} - \sum_j \left(\tau_i - \tau_j\right) \nu_j \gamma_{2i} \\ - \sum_j \left(\tau_i - \tau_j\right)^2 \nu_j \gamma_{3i} - \sum_j \left(\tau_i - \tau_i^*\right)\left(\tau_i - \tau_j\right) \nu_j \gamma_{4i} \end{aligned},$$

which limits consideration to cases in which a county's preference parameters on all pairwise comparisons are the same.

[4] Keen and Konrad (2013) offer an analytical review of this literature.

As shown in Appendix F, the model described by (18) produces implied choices of τ_i that are the same as those in (3), and objective satisfaction levels under harmonization that are the same as in (9), but with independent tax setting produces collective objective satisfaction that differs slightly from (7). As a result, the comparison between harmonization and independent tax setting is modified by replacing $-\sum\left(\tau_i-\overline{\tau}\right)^2 \frac{\gamma_{3i} w_i}{\sum \gamma_{1i} w_i}$ on the right side of (13) with

$-\sum\left(\tau_i-\overline{\tau}\right)^2 \frac{\left[\frac{\gamma_{3i} w_i}{\sum \gamma_{3i} w_i}-\nu_i\right]\sum \gamma_{3i} w_i}{\sum \gamma_{1i} w_i}$. This modification generally has the effect of reducing the impact of the γ_{3i} terms,[5] which dampens any effect of strategic complementarity or strategic substitutability on the comparison between harmonization and independent tax setting.

4. Tax Rate Implications of the Standard Deviation Rule.

The standard deviation rule as expressed in (15) carries important implications for the range of harmonized tax rates that governments may consider adopting. This section first presents implications of the standard deviation rule for efficient harmonized rates, followed by implications of the rule for harmonized rates that governments might choose if they lack sufficient information to determine efficient rates.

4.1. Efficient harmonized tax rates and the harmonization statistic.

An efficient harmonized tax rate, τ_h^*, exceeds the average observed tax rate by the extent to which the average rate is depressed by tax competition; this is captured in equation (11). In addition, in order to be efficient, a harmonized rate must advance collective objectives relative to outcomes with independent tax setting. A positive effect of harmonization on aggregate objective satisfaction requires that the right side of equation (15) is positive, for which there are two critical values of Δ, denoted $\tilde{\Delta}$ in (17). Since (13) implies that

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[5] Notably, the impact of the γ_{3i} terms becomes zero if $\nu_i = \frac{\gamma_{1i} w_i}{\sum \gamma_{1i} w_i}$ and $\hat{\gamma}_{3i} = 0, \forall i$, so that $\gamma_{3i} = \gamma_3 \gamma_{1i}$.

$\frac{1}{\sum \gamma_{1i} w_i} \frac{\partial \left(R\left(\tau_h^*\right) - S \right)}{\partial \Delta} = 2\left[\Delta - \left(\bar{\tau} - \tilde{\tau} \right) \right]$, it follows from (17) that $R\left(\tau_h^*\right) - S > 0$ if either

$\Delta > \left(\bar{\tau} - \tilde{\tau} \right) + \sqrt{1 + \gamma_3 + \gamma_4} \sqrt{\sigma^2 + \xi + \left(\bar{\tau} - \tilde{\tau} \right)^2}$ or $\Delta < \left(\bar{\tau} - \tilde{\tau} \right) - \sqrt{1 + \gamma_3 + \gamma_4} \sqrt{\sigma^2 + \xi + \left(\bar{\tau} - \tilde{\tau} \right)^2}$.

Figure 2 depicts $R\left(\tau_h^*\right) - S$ as a function of Δ. It is evident from the figure that no tax rate in the interval $\left(\bar{\tau} - \sqrt{1 + \gamma_3 + \gamma_4} \sqrt{\sigma^2 + \xi + \left(\bar{\tau} - \tilde{\tau} \right)^2}, \bar{\tau} + \sqrt{1 + \gamma_3 + \gamma_4} \sqrt{\sigma^2 + \xi + \left(\bar{\tau} - \tilde{\tau} \right)^2} \right)$ represents an efficient harmonized rate for any value of Δ.

Confining attention to the larger solution to (17), corresponding to cases in which tax competition lowers average tax rates, values of Δ exceeding $\tilde{\Delta}$ all have the property that $R\left(\tau_h^*\right) - S > 0$. If $\Delta \geq \tilde{\Delta}$, so it is efficient to harmonize tax rates, then since $\tau_h^* = \tilde{\tau} + \Delta$, it follows that $\tau_h^* \geq H$, in which $H = \tilde{\tau} + \tilde{\Delta}$ is the *harmonization statistic*, which from (17) is

(19) $$H \equiv \bar{\tau} + \sqrt{1 + \gamma_3 + \gamma_4} \sqrt{\sigma^2 + \left(\bar{\tau} - \tilde{\tau} \right)^2 + \xi}.$$

The harmonization statistic *H* defined in (19) represents a lower bound on the range of possible efficient harmonized tax rates for cases in which tax competition depresses rates. If $\left(\gamma_3 + \gamma_4 \right) = 0$, so there are no strategic reactions, and additionally $\bar{\tau} = \tilde{\tau}$ and $\xi = 0$, then $H = \bar{\tau} + \sigma$, and the harmonization statistic is simply the sum of the average tax rate and the standard deviation of tax rates. To the degree that tax rates are strategic complements, then *H* exceeds $\bar{\tau} + \sigma$, and if tax rates are strategic substitutes, then *H* is less than $\bar{\tau} + \sigma$. A high value of $\bar{\tau}$ relative to $\tilde{\tau}$ puts upward pressure on *H,* as does a positive value of ξ. It remains the case that $\tau_h^* = \tilde{\tau} + \Delta$, which describes a point rather than a range; but application of *H* permits the analyst to narrow the range of possible values that τ_h^* may take.

4.2. Rates that advance collective objectives.

If governments suspect that tax competition depresses rates, but do not know the value of Δ, then it is not possible to choose an efficient harmonized tax rate, or indeed, even to verify that tax harmonization would advance collective objectives. Governments may nonetheless decide to harmonize their tax rates. Under these circumstances, it is helpful to identify harmonized tax rates that support greater attainment of collective objectives.

A tax harmonization agreement designed to reverse a downward effect of tax competition will raise rates by imposing $\tau_h > \overline{\tau}$. For τ_h in this range, equation (10) implies that the Δ value, denoted $\hat{\Delta}$, at which $R\left(\tau_h\right) = S$, is given by

$$(20) \qquad \hat{\Delta} = \frac{\tau_h^2 + \left(1+\gamma_3+\gamma_4\right)\left[\sigma^2 + \xi + \left(\overline{\tau} - \tilde{\tau}\right)^2\right] + 2\tilde{\tau}\left(\overline{\tau} - \tau_h\right) - \overline{\tau}^2}{2\left(\tau_h - \overline{\tau}\right)}.$$

Since (10) also implies that $\frac{1}{\sum \gamma_{1i} w_i} \frac{\partial\left[R\left(\tau_h\right) - S\right]}{\partial \Delta} = 2\left(\tau_h - \overline{\tau}\right)$, it follows that $\frac{\partial\left[R\left(\tau_h\right) - S\right]}{\partial \Delta} > 0$ for any $\tau_h > \overline{\tau}$. Consequently, tax harmonization at rate $\tau_h > \overline{\tau}$ entails $R\left(\tau_h\right) > S$ for any Δ exceeding $\hat{\Delta}$. If Δ is unknown, then the probability that a harmonized tax rate advances collective objectives is the probability that Δ exceeds $\hat{\Delta}$ as expressed in equation (20); and this probability is maximized by adopting a value of τ_h that minimizes $\hat{\Delta}$.

Differentiating (20) with respect to τ_h yields

$$(21) \qquad \frac{4\left(\tau_h - \tilde{\tau}\right)\left(\tau_h - \overline{\tau}\right) - 2\tau_h^2 - 2\left(1+\gamma_3+\gamma_4\right)\left[\sigma^2 + \xi + \left(\overline{\tau} - \tilde{\tau}\right)^2\right] - 4\tilde{\tau}\left(\overline{\tau} - \tau_h\right) + 2\overline{\tau}^2}{4\left(\tau_h - \overline{\tau}\right)^2}.$$

Identifying the minimum by setting (21) equal to zero, and applying the quadratic formula to the numerator of (21) to solve for τ_h, produces $\tau_h = H$: a harmonized tax rate equal to the harmonization statistic defined in (19) maximizes the probability that tax harmonization advances collective objectives.

If tax competition depresses average tax rates so little that $\Delta < \tilde{\Delta}$, taking $\tilde{\Delta}$ to be the larger of the two values defined by (17), then it is not possible for any harmonized tax to advance collective objectives. If $\Delta = \tilde{\Delta}$, then H is the efficient harmonized rate, and indeed the only harmonized rate that does not impede the attainment of collective objectives. And for any value of $\Delta > \tilde{\Delta}$, a harmonized tax at rate *H* will advance collective objectives, even though *H* would not be the efficient harmonized rate. A harmonized tax rate other than *H* advances collective objectives for only a portion of the range of Δ for which *H* would do so, which is why harmonizing at *H* maximizes the probability of advancement.

5. Harmonizing Corporate Tax Rates in 2020.

In order to use (13) to evaluate whether corporate tax rate harmonization advances collective objectives, or (19) to inform the choice of a harmonized tax rate, it is necessary to specify the $\frac{\gamma_{1i} w_i}{\sum \gamma_{1i} w_i}$ weights used to calculate the variance and other terms in the expression, 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 $\frac{\gamma_{1i}}{\sum \gamma_{1i}}$ weights capture relative willingness to pay to avoid disfavored tax rates. If willingness to pay is proportional to business activity as proxied by GDP, then the first term on the right side of (13) is the square of the effect of tax competition on GDP-weighted average tax rates, and the second term is the GDP-weighted tax rate variance. Using GDP weights to proxy for $\frac{\gamma_{1i} w_i}{\sum \gamma_{1i} w_i}$ relies on the assumption that countries with similar incomes find it equally costly to deviate from their preferred business 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 relative intensities of country preferences, GDP weights are reasonable choices, capturing the obvious effects of economic scale on the consequences of taxes and therefore the amounts that countries are likely willing to pay.

5.1. Harmonization statistics for 2020.

Table 1 presents harmonization statistics for world statutory corporate tax rates, using tax rate data for 2020 reported by the Tax Foundation.[6] The table presents harmonization statistics for three different specifications of the $\frac{\gamma_{1i} w_i}{\sum \gamma_{1i} w_i}$ weights: GDP, population, and equal country weights. The table offers calculations of *H* for five different specifications of the ν_i weights used to calculate $\bar{\tau}$, the world average rate against which countries compare their own rates: GDP, population, equal country weights, GDP weights restricted only to tax haven countries, and all weights assigned to zero-tax countries. And the table considers three specifications of the γ_3 and γ_4 parameters: $\gamma_3 = \gamma_4 = 0$, corresponding to $d\tau_i / d\bar{\tau} = 0$; $\gamma_3 = 0.4$ and $\gamma_4 = 0.1$, corresponding to $d\tau_i / d\bar{\tau} = 0.3$; and $\gamma_3 = 1.0$ and $\gamma_4 = 0.2$, corresponding to $d\tau_i / d\bar{\tau} = 0.5$. All of the calculations assume that $\xi = 0$.

The top panel of Table 1 indicates that, for the 178 countries and territories for which the Tax Foundation reports data and it is possible to obtain GDP information, the GDP-weighted mean corporate tax rate was 25.85%, with a standard deviation of 4.54%. If collective decision makers weight outcomes by GDP, and countries compare their own tax rates to a GDP-weighted average of world rates, then the harmonization statistic is 30.38 in the absence of strategic reactions, and somewhat larger with strategic complementarity, rising to 32.58 in the scenario in which $\frac{\partial \tau_i}{\partial \bar{\tau}} = 0.5$. Hence if there is an efficient harmonized tax rate, it likely exceeds 30.4%. GDP is the most natural weight to use in calculating $\bar{\tau}$, as the relevance of foreign tax rates depends on potential economic activity, but the table presents calculations using alternative weights for comparison. The harmonization statistic calculated using population weights is 31.38, and is 28.81 when calculated using equal weights for every country and territory, the smaller figure reflecting the lower average tax rates of smaller countries.

If countries are particularly concerned about profit shifting, then in constructing $\bar{\tau}$ they might attach disproportionately high weights to tax rates available in tax haven countries.

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[6] https://taxfoundation.org/publications/corporate-tax-rates-around-the-world/

Taking a somewhat extreme version of this approach, column four of Table 1 presents harmonization statistics based on $\overline{\tau}$ calculated using GDP weights for tax haven countries exclusively;[7] and the calculations in column five go even further, assigning weights only to zero-tax countries. The resulting harmonization statistics are 27.06 in the case of tax haven weights and 26.24 in the case of zero-tax weights, consierably smaller than in other scenarios, though the harmonization statistic with zero-tax weights increases sharply if tax choices exhibit strategic complementarity. Heavily weighting the tax rates of low-tax countries significantly reduces $\overline{\tau}$ while increasing $\left(\tilde{\tau}-\overline{\tau}\right)^2$, which generally reduces the harmonization statistic in the absence of strategic reactions, but can increase H if tax rates display strong complementarity.

The middle panel of Table 1 presents harmonization statistics for scenarios in which collective decisions weight outcomes by country population rather than GDP. Since GDP is the product of population and per-capita GDP, decision makers might use population weights if their criterion were the product of aggregate willingness to pay (measured by GDP) and the marginal value of resources (proxied by the inverse of per capita GDP). As it happens, the harmonization statistics in the middle panel of Table 1 differ only slightly from those in the top panel that are based on GDP weights. And a third possibility is that the nature of collective decision making is such that deviations from preferred tax rates of every country and territory receive equal weights, regardless of jurisdiction size or willingness to pay; the bottom panel of Table 1 presents harmonization statistics corresponding to this collective decision rule. This equal country weighting reduces the calculated average tax rate and increases its standard deviation, which with GDP or population weights used to calculate $\overline{\tau}$ significantly increases the harmonization statistic, but this effect changes sign when zero-tax countries receive exclusive weights in calculating $\overline{\tau}$.

5.2. Changes over time.

The figures in Table 1 suggest that, other than in cases when governments are exclusively concerned with tax havens, the tax harmonization statistic for 2020 is roughly 30 percent or higher. This represents a significant decline relative to recent decades. Table 2 presents values of $\tilde{\Delta}$, the critical value of the effect of tax competition on tax rates, at decadal intervals between

[7] Tax haven countries are those identified by Hines (2010).

1980 and 2020, taking $\xi = 0$ and $\gamma_3 + \gamma_4 = 0$. Using GDP weights, $\tilde{\Delta}$ declined from 7.81 in 1980 to 4.54 in 2020, while over the same period that the average tax rate declined from 46.52% to 25.85%. Other weighting schemes produce similar reductions in $\tilde{\Delta}$ and average tax rates. The combination of a lower $\tilde{\Delta}$ and a much lower average tax rate significantly reduces the implied harmonization statistic. And to the extent that a declining average tax rate reflects a rising value of Δ, a lower corporate tax rate together with a smaller value of $\tilde{\Delta}$ suggests that over time there is an increasing likelihood that harmonization would advance collective objectives.

The information in Table 2 does not come from a balanced panel, as data limitations restrict the sample to 178 countries and territories in 2020, 159 in 2010, 145 in 2000, and 93 in 1990 and 1980. In an effort to limit the degree to which any intertemporal patterns are affected by sample selection, Table 3 presents $\tilde{\Delta}$ values for a balanced panel of 55 countries for which it is possible to obtain data for all years. The pattern looks very similar to that apparent in Table 2 for the larger but unbalanced panel.

5.3. Harmonizing effective average 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 can also play important roles. Consequently, an analysis of statutory corporate tax rates offers an incomplete picture of relative tax burdens – though is informative about the effects of harmonizing statutory corporate tax rates. In practice, corporate tax rate changes are often accompanied by tax base changes (Kawano and Slemrod, 2016), which is why international agreements to harmonize taxes are likely to include restrictions to any offsetting tax base changes that countries might otherwise be inclined to adopt.

It is useful to consider the extent to which the patterns evident in Tables 2 and 3 persist with tax rates defined in a manner that adjusts for tax base changes. Devereux and Griffith (2003) propose a method of calculating effective average corporate tax rates relevant to location choices by multinational firms. This effective average corporate tax rate measure is sensitive to tax base definitions, and serves as the basis of the calculations by Spengel et al. (2021) of effective corporate tax burdens in EU and other high-income countries. These data are available for only 35 countries in 2020 and 2010, and 28 countries in 2000. As a result of this limited coverage, the *H* statistics and $\tilde{\Delta}$ values that can be calculated from this sample of countries correspond to partial harmonizations of just their tax rates.

Table 4 presents values of $\tilde{\Delta}$ calculated using these effective average tax rates for the 35-country coalition for 2020 and 2010. Using GDP weights in calculating collective objectives and in constructing $\bar{\tau}$, the critical value of Δ declined from 6.82 in 2010 to 5.16 in 2020, the same period of time over which the mean tax rate declined from 32.33% to 26.43%. Implied $\tilde{\Delta}$ likewise declines if $\bar{\tau}$ is measured using population or equal weights, or if weights are assigned exclusively to tax haven countries. Use of GDP weights produces a partial harmonization *H* statistic of 31.59 for 2020, which is significantly lower than the corresponding partial harmonization *H* statistic of 39.15 for 2010.

Table 5 reports the results of calculating $\tilde{\Delta}$ with statutory corporate tax rates for the same sample of countries as that used in the Table 4 calculations. These values of $\tilde{\Delta}$ also clearly declined between 2010 and 2020, doing so in every specification of weights used for collective decisions and tax rate comparisons. For example, using GDP weights, $\tilde{\Delta}$ was 6.46 in 2010 and 3.86 in 2020. The average statutory tax rate of this sample of countries also declined significantly over time, reducing the implied *H* statistic from 40.28 in 2010 to 29.79 in 2020. While the statutory tax rate *H* statistic moves in the same direction as the effective average tax rate *H* statistic, it is clear that the magnitude of the change is sensitive both to the type of tax and to the sample of countries chosen for the partial harmonization exercise.[8]

[8] Appendix G presents analogous calculations for the 28-country sample for which effective tax rate data are available for 2000, 2010, and 2020. Over this longer time span, and for this smaller sample of countries, there is less obvious downward movement of $\tilde{\Delta}$, though average effective tax rates consistently decline over this period. The implied effective average tax rate *H* statistics decline from 38.91 in 2000 to 31.91 in 2010 and 29.83 in 2020; similarly, the implied statutory tax rate *H* statistics decline from 46.77 in 2000 to 33.50 in 2010 and 30.81 in 2020.

6. *Tax Competition and Tax Rate Determination.*

Competitive tax rate-setting can become a race to the bottom, producing tax rates that are very low or even zero. There is considerable controversy over the likelihood and course of such a race to the bottom in business tax rates,[9] and a lively possibility that incentives to engage in tax exporting by imposing higher taxes, the burden of which is partially borne by foreigners, could offset or even reverse the race to the bottom.[10] Many workhorse models of tax competition carry the implication that tax rates are strategic complements,[11] though some have the feature that tax rates can be strategic substitutes,[12] with countries reacting to foreign rate reductions by increasing their own tax rates.

Empirical investigation of the role of competition in corporate tax policy determination confronts a limited availability of exogenous changes with which to estimate the magnitudes of any competitive effects. Despite this challenge, it is possible to draw important lessons from patterns in the data, the first and most obvious of which is that corporate tax rates are not all zero, thereby firmly rejecting the simplest version of a race to the bottom model. A second clear feature of international experience is that statutory corporate tax rates have fallen significantly since 1980,[13] which is consistent with countries adjusting their corporate tax systems to competitive pressures in an increasingly globalized world. Smaller countries tend to have lower tax rates,[14] which is likewise consistent with competition exerting significant pressures on tax rates.[15] Estimated reaction functions often suggest that tax rates are strategic complements,[16]

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[9] 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) note that if governments have limited tax instruments then with sufficient taxpayer heterogeneity there may not be a Nash equilibrium of any kind in the tax-setting game.

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

[11] Many of these studies are surveyed in Wilson (1999) and Keen and Konrad (2013). Rota-Graziosi (2019) identifies sufficient conditions for the Nash game in tax rates to be supermodular, in which case the Nash equilibrium exists and has the property that tax rates are strategic complements. The Rota-Graziosi paper notes that it is much more straightforward to identify sufficient conditions for supermodularity when the government is assumed to choose tax rates to maximize tax revenue than when the government chooses tax rates to maximize welfare.

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

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

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

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

though these findings may be sensitive to specifications that, if modified, can yield the conclusion that tax rates are strategic substitutes,[17] or that they are neither complements nor substitutes.[18]

Coalitions of governments occasionally contemplate harmonizing reforms of direct and indirect taxation. There is considerable interest in the welfare properties of commodity tax harmonization within a federation, a category of potential reform that bears some resemblance to the harmonization evaluated in section 3.[19] Corporate tax harmonization raises additional issues, including the role of government commitment,[20] the impact of potentially limited international capital mobility,[21] and the conditions under which capital tax harmonization by a coalition of countries might represent a Pareto improvement.[22] There are estimates of the potential welfare effects of harmonizing U.S. state business taxes,[23] and considerable interest in the potential consequences of harmonizing European business taxes.[24]

7. Conclusion.

Countries choose tax policies based on many considerations, including revenue needs, economic conditions, distributional preferences, and prevailing notions of sound fiscal policy.

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[16] 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.

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

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

[19] Important contributions to the commodity tax harmonization literature include Keen (1987, 1989), Abe and Okamura (1989), Kanbur and Keen (1993), Haufler (1996), Lopez-Garcia (1996, 1998), Lockwood (1997), Keen, Lahiri, and Raimondos-Møller (2002), Ohsawa (2003), Kotsogiannis, Lopez-Garcia, and Myles (2005), Kotsogiannis and Lopez-Garcia (2007, 2021), Hashimzade, Khodavaisi, and Myles (2011), Agrawal (2012, 2015), and Karakosta, Kotsogiannis, and Lopez-Garcia (2014). Many of these papers analyze two-country problems that, if extended to settings with multiple countries, would not have the feature that government objectives are functions of own tax rates and a common weighted average of world tax rates.

[20] Kehoe (1989) identifies circumstances in which the absence of credible commitment adversely affects the potential desirability of coordinated governmental efforts such as tax harmonization, and Conconi, Perroni, and Riezman (2008) note that credibility concerns may enhance the attractiveness of a partial tax harmonization alternative.

[21] See, for example, Konrad (2008), which analyzes endogenous capital mobility.

[22] See, for example, Konrad and Schjelderup (1999) and Bucovetsky (2009).

[23] See Wildasin (1989), Parry (2003), Fajgelbaum et al. (2019), and Ferrari and Ossa (2023).

[24] See, for example, Genser and Haufler (1996), Eggert and Genser (2001), Goodspeed (2002), Sørensen (2004), Bettendorf et al. (2010), and Osterloh and Heinemann (2013).

These considerations do not bear equally on all governments, which is why they select different tax rates when they have the freedom to do so. As a result, there is valuable information about the dispersion of preferences in the tax rates that countries choose.

Tax competition typically reduces business tax rates. Coordinated action can address the effects of tax competition, but common coordination methods such as tax harmonization require strict adherence to uniform rules that limit their appeal. As a result, tax harmonization can advance collective objectives only if the standard deviation of tax rates is less than the average effect of tax competition. Alternative coordination devices such as minimum tax rules afford some dimensions of design flexibility, though almost all impose restrictions that are insensitive to individual differences.[25] Consequently, an evaluation of the impact of tax harmonization or any other tax coordination device entails weighing the costs of imposed uniformity against the benefits of controlling average rates.

In recent decades, world corporate tax rates have declined substantially, and to a lesser degree, the standard deviation of corporate tax rates has also declined. Both trends point in the direction of making tax harmonization more attractive to governments. Declining tax rates suggest a growing impact of tax competition on average rates, and a declining standard deviation suggests that the cost of requiring governments to adopt uniform rates may be falling over time. These are important considerations, though any evaluation of the potential consequences of tax harmonization depends on the details of its implementation and enforcement.

This paper analyzes international business taxation, but the second order approximation that is the basis of the analysis applies more generally to any competitive context. This includes subnational taxation and many other government policies with competitive implications, such as environmental and other business regulations. The extent to which harmonizing any of these policies is consistent with advancing collective objectives should be functions of both the average impact of competition and the extent of policy dispersion in the absence of coordination.

[25] The most prominent and important recent example is the worldwide corporate minimum tax proposed by the OECD (2021) and approved in concept by more than 100 countries. For analysis of the impact of minimum tax rules, see Peralta and van Ypersele (2006), Konrad (2009), Kiss (2012), Hebous and Keen (2021), Johannesen (2022), Janeba and Schjelderup (2023), and Hines (2023).

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Figure 1
Decomposing the Criterion for Efficient Tax Harmonization

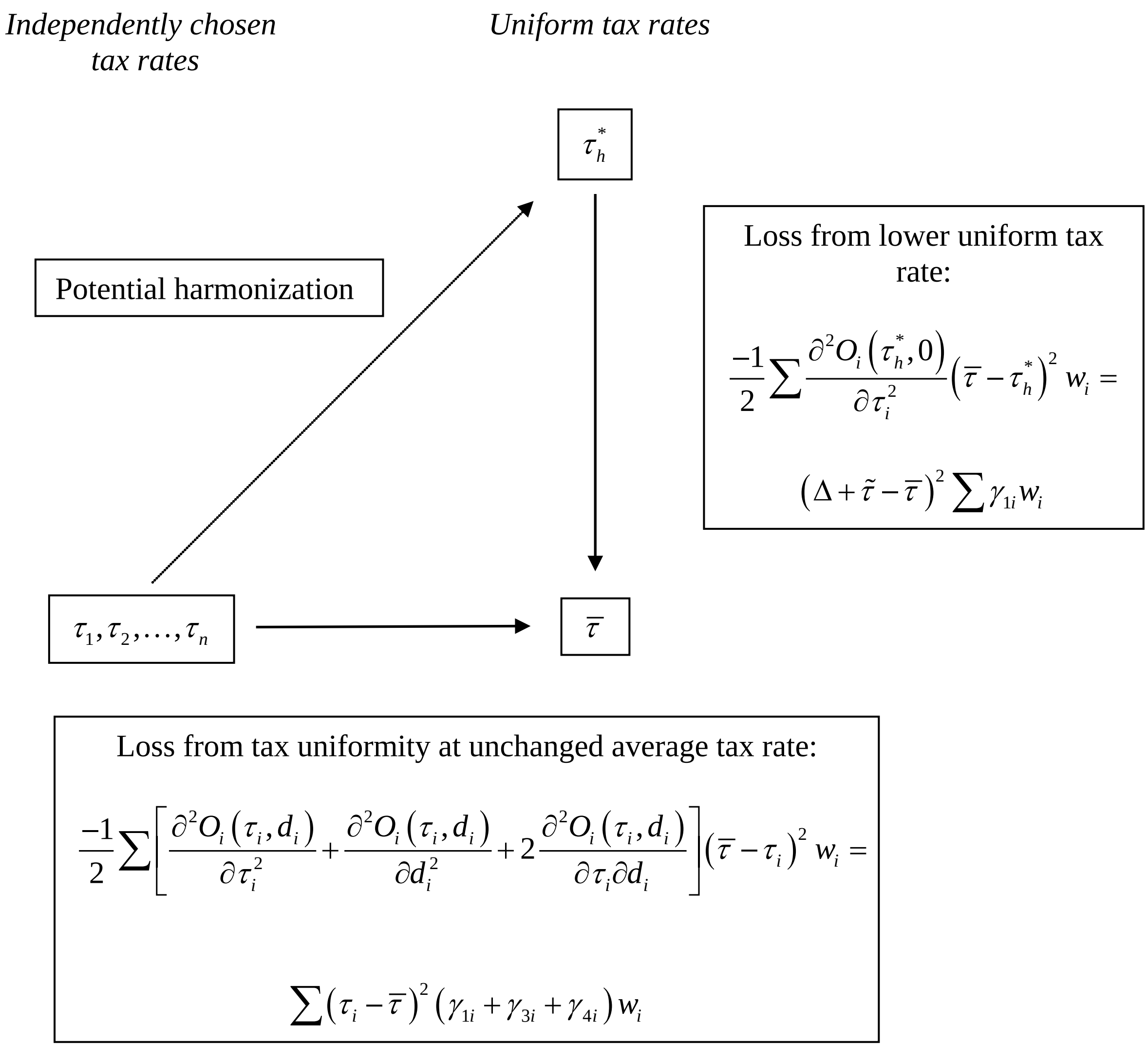
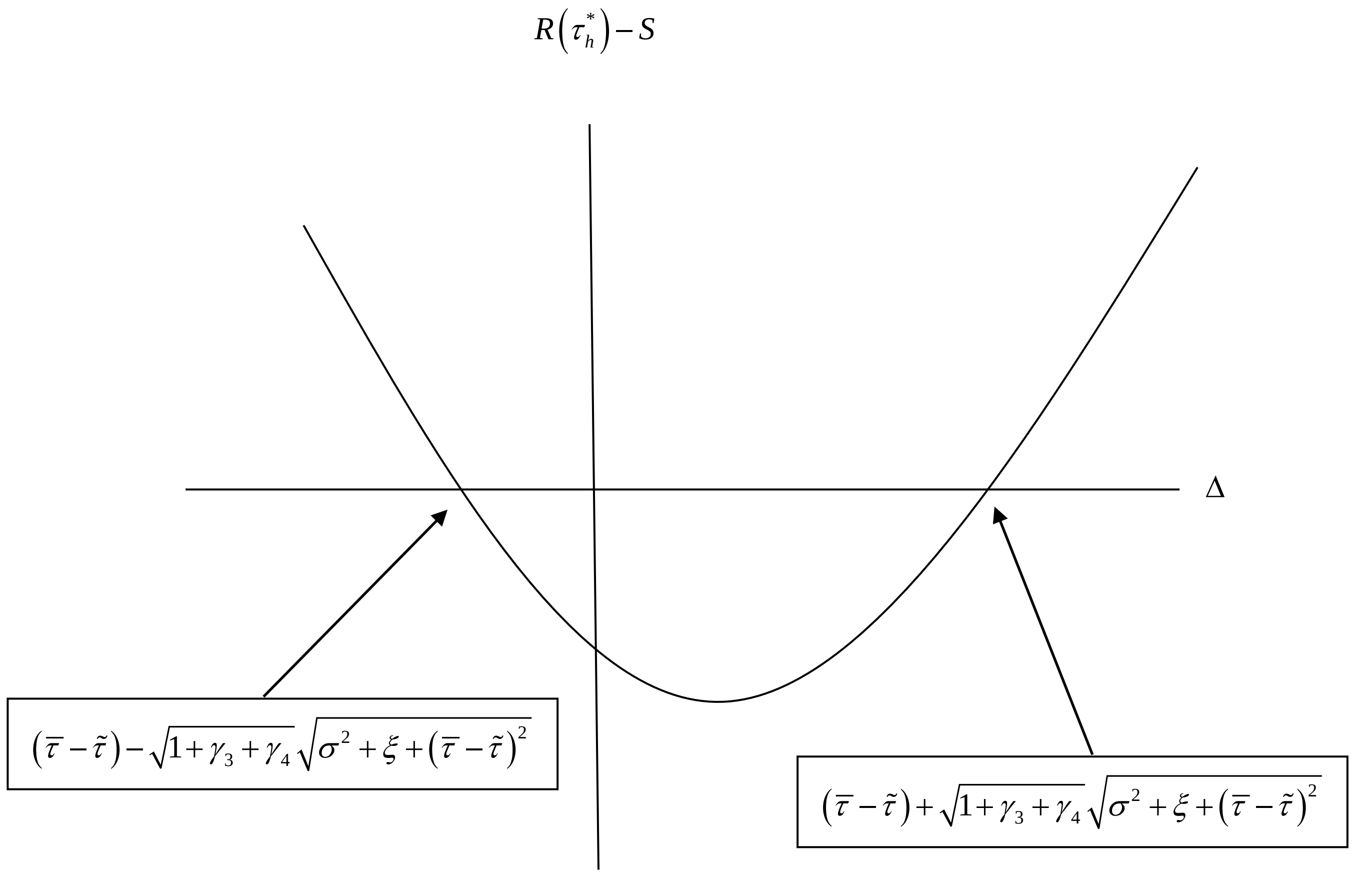


Figure 1 illustrates that independent tax setting can be evaluated relative to objective-maximizing tax harmonization by comparing both of these alternatives to a third possibility, uniform taxes at the original average tax rate. Replacing independently chosen tax rates with their mean value produces a second-order loss for every country, the aggregate value of which is $\sum(\tau_i-\overline{\tau})^2(\gamma_{1i}+\gamma_{3i}+\gamma_{4i})w_i$. Replacing uniform tax rates of τ_h^* with uniform tax rates of $\overline{\tau}$ produces second-order losses with aggregate value $(\tau_h^*-\overline{\tau})^2\sum\gamma_{1i}w_i=(\Delta+\tilde{\tau}-\overline{\tau})^2\sum\gamma_{1i}w_i$.

Figure 2
Effects of Efficient Tax Harmonization at Different Values of Δ



Note to Figure 2: the figure depicts the net effect of efficient tax harmonization on collective objectives, $R\left(\tau_h^*\right)-S$, as a function of Δ, the effect of tax competition on average tax rates.

Table 1
Harmonization Statistics (*H*), 2020

γ_{1i} *weights*	$\tilde{\tau}$	σ	*H statistic* ν_i *weights* **GDP**	**Pop**	**Unw**	**Havens**	**0**
GDP	25.85	4.54					
$\gamma_3 = \gamma_4 = 0$			30.38	31.38	28.81	27.06	26.24
$\gamma_3 = 0.4; \gamma_4 = 0.1$			31.41	32.42	29.92	29.10	32.14
$\gamma_3 = 1.0; \gamma_4 = 0.2$			32.58	33.61	31.20	31.45	38.92
Population	26.75	4.56					
$\gamma_3 = \gamma_4 = 0$			30.49	31.31	29.26	27.87	27.14
$\gamma_3 = 0.4; \gamma_4 = 0.1$			31.54	32.33	30.47	30.09	33.23
$\gamma_3 = 1.0; \gamma_4 = 0.2$			32.74	33.51	31.87	32.64	40.25
Unweighted	23.86	7.53					
$\gamma_3 = \gamma_4 = 0$			33.63	34.82	31.38	27.53	25.01
$\gamma_3 = 0.4; \gamma_4 = 0.1$			35.38	36.63	33.08	29.68	30.64
$\gamma_3 = 1.0; \gamma_4 = 0.2$			37.40	38.71	35.02	32.14	37.10

Note to Table 1: the table presents harmonization statistics (*H*) for world statutory corporate tax rates in 2020. The top panel uses calculations that weight country objectives by GDP, and presents *H* for three strategic reaction scenarios: $\gamma_3 = \gamma_4 = 0$, corresponding to $d\tau_i / d\overline{\tau} = 0$; $\gamma_3 = 0.4$ and $\gamma_3 = 0.1$, corresponding to $d\tau_i / d\overline{\tau} = 0.3$; and $\gamma_3 = 1.0$ and $\gamma_4 = 0.2$, corresponding to $d\tau_i / d\overline{\tau} = 0.5$. $\tilde{\tau}$ is the average statutory tax rate calculated using these weights, and σ is the weighted standard deviation. The table presents values of *H* for each of five relative weights ν_i used to calculate the tax rate $\overline{\tau}$ against which countries compare their own tax rates: GDP; population; equal weights for all countries; all weights on tax haven countries, prorated by GDP; and all weights assigned to zero-tax-rate countries. The second panel repeats these calculations, weighting country objectives by population; and the third panel repeats the calculations with equal weights for all countries. All calculations assume that $\xi = 0$. The calculations use statutory corporate tax rate data reported by the Tax Foundation for 178 countries and territories for which the World Bank reports GDP and population data.

Table 2
Tax Competition Critical Values $\left(\tilde{\Delta}\right)$, 1980-2020 (unbalanced sample)

Year	**Population statistics**		$\tilde{\Delta}$ **values**				
			ν_i *weights*				
γ_{1i} *weights*	$\tilde{\tau}$	σ	**GDP**	**Pop**	**Unw**	**Havens**	**0**
2020							
GDP	25.85	4.54	4.54	5.53	2.96	1.22	0.40
Population	26.75	4.56	3.74	4.56	2.51	1.11	0.39
Unweighted	23.86	7.53	9.78	10.96	7.53	3.68	1.16
2010							
GDP	31.15	7.37	7.37	5.55	3.34	1.97	0.86
Population	29.02	6.23	8.70	6.23	3.25	1.68	0.66
Unweighted	24.69	9.04	17.56	14.35	9.04	4.68	1.60
2000							
GDP	37.48	6.64	6.64	4.99	2.94	1.54	0.58
Population	35.56	5.63	7.87	5.63	2.87	1.30	0.44
Unweighted	31.47	9.14	16.96	14.11	9.14	4.34	1.30
1990							
GDP	41.33	8.23	8.23	9.01	5.05	2.68	0.81
Population	42.07	8.27	7.56	8.27	4.70	2.56	0.81
Unweighted	37.15	12.73	17.58	18.57	12.73	7.46	2.12
1980							
GDP	46.52	7.81	7.81	13.40	3.70	2.21	0.65
Population	50.94	8.78	5.41	8.78	3.11	2.12	0.75
Unweighted	40.11	12.94	20.84	27.70	12.94	8.08	2.04

Note to Table 2: the table presents critical values $\left(\tilde{\Delta}\right)$ of the impact of tax competition – these are the smallest effects of tax competition on average tax rates for which it would be possible for tax harmonization to advance collective objectives. The calculations are based on world statutory corporate tax rates reported by the Tax Foundation for jurisdictions for which the World Bank also reports GDP and population data. The data cover 178 countries and territories in 2020, 159 in 2010, 145 in 2000, and 93 in 1990 and 1980. Δ is calculated assuming that $\xi = 0$ and $\gamma_3 + \gamma_4 = 0$. Calculations reported in the top row for each year weight country objectives by GDP; those reported in the middle row weight country objectives by population; and those in the bottom row apply equal weights for all countries. $\tilde{\tau}$ is the average statutory tax rate calculated using these weights, and σ is the weighted standard deviation. The table presents $\tilde{\Delta}$ for each of five relative weights ν_i used to calculate the tax rate $\overline{\tau}$ against which countries compare their own tax rates: GDP; population; equal weights for all countries; all weights on tax haven countries, proportional to GDP; and all weights assigned to zero-tax-rate countries.

Table 3
Tax Competition Critical Values $\left(\tilde{\Delta}\right)$, 1980-2020 (balanced sample)

Year	**Population statistics**		$\tilde{\Delta}$ **values**				
			ν_i *weights*				
γ_{1i} *weights*	$\tilde{\tau}$	σ	**GDP**	**Pop**	**Unw**	**Havens**	**0**
2020							
GDP	25.85	4.37	4.37	6.15	2.64	0.91	0.37
Population	27.37	3.66	2.44	3.66	1.47	0.56	0.24
Unweighted	23.54	8.43	11.05	13.09	8.43	3.68	1.46
2010							
GDP	32.02	7.13	7.13	5.30	3.06	1.50	0.78
Population	29.88	5.36	7.91	5.36	2.45	0.99	0.48
Unweighted	25.24	9.07	18.11	14.83	9.07	3.68	1.58
2000							
GDP	35.97	5.34	5.34	4.59	2.01	1.00	0.39
Population	35.16	4.74	5.62	4.74	1.81	0.84	0.32
Unweighted	29.88	9.42	17.31	16.08	9.42	4.50	1.45
1990							
GDP	37.35	5.69	5.69	10.41	3.13	1.77	0.43
Population	41.00	7.20	4.42	7.20	2.97	2.00	0.63
Unweighted	33.74	11.73	15.87	21.05	11.73	7.95	1.98
1980							
GDP	46.62	7.76	7.76	13.46	3.43	2.07	0.64
Population	51.11	8.93	5.50	8.93	3.05	2.09	0.77
Unweighted	39.55	12.97	21.84	28.93	12.97	8.02	2.07

Note to Table 3: the table presents critical values $\left(\tilde{\Delta}\right)$ of the impact of tax competition, performing the calculations of Table 2 on a balanced panel of 55 countries for which it is possible to obtain statutory tax rate, GDP, and population data for all years.

Table 4
Tax Competition Critical Values $(\tilde{\Delta})$, Effective Average Tax Rates

Year	Population statistics		$\tilde{\Delta}$ values				
			ν_i *weights*				
γ_{1i} *weights*	$\tilde{\tau}$	σ	**GDP**	**Pop**	**Unw**	**Havens**	**0**
2020							
GDP	26.43	5.16	5.16	3.96	1.73	1.35	0.50
Population	25.04	6.29	7.84	6.29	2.88	2.22	0.78
Unweighted	19.59	6.24	16.10	13.73	6.24	4.32	0.97
2010							
GDP	32.33	6.82	6.82	5.05	2.04	1.53	0.71
Population	30.26	8.04	10.38	8.04	3.25	2.39	1.05
Unweighted	21.94	7.89	23.44	19.78	7.89	4.84	1.37

Note to Table 4: the table presents critical values $(\tilde{\Delta})$ of the impact of tax competition, performing the calculations of Table 2 using effective average corporate tax rates rather than statutory tax rates. The sample is a balanced panel of 35 countries for which it is possible to obtain effective average tax rate data for both 2010 and 2020.

Table 5
Tax Competition Critical Values $(\tilde{\Delta})$, Statutory Rates, EATR Sample

Year	Population statistics		$\tilde{\Delta}$ values ν_i *weights*				
γ_{1i} *weights*	$\tilde{\tau}$	σ	**GDP**	**Pop**	**Unw**	**Havens**	**0**
2020							
GDP	25.93	3.86	3.86	3.25	1.47	0.94	0.29
Population	25.26	4.51	5.23	4.51	2.14	1.36	0.40
Unweighted	21.59	6.37	12.05	11.02	6.37	3.96	0.92
2010							
GDP	33.82	6.46	6.46	4.67	1.90	1.37	0.61
Population	31.69	7.81	10.23	7.81	3.21	2.25	0.95
Unweighted	23.79	7.94	22.82	19.09	7.94	4.62	1.29

Note to Table 5: the table presents critical values $(\tilde{\Delta})$ of the impact of tax competition, performing the calculations of Table 2 using statutory corporate tax rates. The sample is the balanced panel of 35 countries analyzed in the calculations reported in Table 4.

Appendix A

This appendix offers a derivation of equation (7) in section 2.3 of the text. Equation (3) implies that

$$\text{(A1)} \qquad \tau_i^* = \tau_i + \frac{\left(\tau_i - \overline{\tau}\right)\left(\gamma_{3i} + \frac{\gamma_{4i}}{2}\right) + \frac{\gamma_{2i}}{2}}{\gamma_{1i} + \frac{\gamma_{4i}}{2}}.$$

Equations (1) and (A1) together imply that if country *i* chooses its tax rate to maximize $O_i\left(\tau_i, d_i\right)$, then its objective level is

$$\text{(A2)} \qquad \begin{aligned} O_i\left(\tau_i, d_i\right) = {} & O_i\left(\tau_i^*, 0\right) - \tau_i^{*2}\gamma_{1i} - \tau_i^{\,2}\gamma_{1i} + 2\tau_i^{\,2}\gamma_{1i} + 2\frac{\tau_i\left[\left(\tau_i - \overline{\tau}\right)\left(\gamma_{3i} + \frac{\gamma_{4i}}{2}\right) + \frac{\gamma_{2i}}{2}\right]\gamma_{1i}}{\gamma_{1i} + \frac{\gamma_{4i}}{2}} \\ & - \left(\tau_i - \overline{\tau}\right)\gamma_{2i} - \left(\tau_i - \overline{\tau}\right)^2\gamma_{3i} + \frac{\left(\tau_i - \overline{\tau}\right)\left[\left(\tau_i - \overline{\tau}\right)\left(\gamma_{3i} + \frac{\gamma_{4i}}{2}\right) + \frac{\gamma_{2i}}{2}\right]\gamma_{4i}}{\gamma_{1i} + \frac{\gamma_{4i}}{2}} \end{aligned}.$$

Collecting terms and simplifying, (A2) implies that

$$\text{(A3)} \qquad \begin{aligned} O_i\left(\tau_i, d_i\right) = {} & O_i\left(\tau_i^*, 0\right) - \tau_i^{*2}\gamma_{1i} + \left(\tau_i - \overline{\tau}\right)^2\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right) - \overline{\tau}^{\,2}\gamma_{1i} + 2\overline{\tau}\tau_i\gamma_{1i} \\ & + 2\frac{\overline{\tau}\left(\tau_i - \overline{\tau}\right)\left(\gamma_{3i} + \frac{\gamma_{4i}}{2}\right)\gamma_{1i}}{\gamma_{1i} + \frac{\gamma_{4i}}{2}} + \overline{\tau}\,\frac{\gamma_{2i}\gamma_{1i}}{\gamma_{1i} + \frac{\gamma_{4i}}{2}} \end{aligned}.$$

Applying the definition of Δ in (6), together with (A1) and the aggregation rule (5), means that

$$\text{(A4)} \qquad \begin{aligned} S = {} & \sum O_i\left(\tau_i^*, 0\right)w_i - \sum \tau_i^{*2}\gamma_{1i}w_i + \sum\left(\tau_i - \overline{\tau}\right)^2\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right)w_i \\ & - \overline{\tau}^{\,2}\sum\gamma_{1i}w_i + 2\overline{\tau}\left(\tilde{\tau} + \Delta\right)\sum\gamma_{1i}w_i \end{aligned},$$

which is identical to (7) in the text.

Appendix B

This appendix characterizes unrestricted tax choices that maximize collective objectives.

If tax competition reduces affects tax rates, then neither tax harmonization nor unfettered tax competition maximizes collective objectives. Maximizing (5) over an unrestricted choice of τ_i, and applying the approximation in (1), yields the first order condition

(B1) $$2\gamma_{1i}\left(\tau_i^* - \hat{\tau}_i\right)w_i - \gamma_{2i}w_i + 2\gamma_{3i}\left(\overline{\tau} - \hat{\tau}_i\right)w_i + \gamma_{4i}\left(\overline{\tau} + \tau_i^* - 2\hat{\tau}_i\right)w_i + \frac{\partial S}{\partial \overline{\tau}}v_i = 0, \forall i,$$

in which $\hat{\tau}_i$ is the value of τ_i that maximizes (5), and $\frac{\partial S}{\partial \overline{\tau}}$ is given by

(B2) $$\frac{\partial S}{\partial \overline{\tau}} = \sum \gamma_{2i}w_i + 2\sum\left(\hat{\tau}_i - \overline{\tau}\right)\gamma_{3i}w_i + \sum\left(\hat{\tau}_i - \tau_i^*\right)\gamma_{4i}w_i \; .$$

Equation (B1) implies that

(B3) $$\hat{\tau}_i = \tau_i + \frac{\frac{\partial S}{\partial \overline{\tau}}v_i}{2\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right)w_i}.$$

Equation (B3) indicates that the tax rates that maximize collective objective satisfaction differ from the rates that countries choose independently; furthermore, these objective-maximizing rates are nonuniform. Equation (B3) indicates that if $\frac{\partial S}{\partial \overline{\tau}} > 0$ then objective-maximizing tax rates all exceed the rates that countries choose independently; and the opposite is the case if $\frac{\partial S}{\partial \overline{\tau}} < 0$.

Appendix C

This appendix considers the tax-setting behavior implied by different values of $\left(\gamma_3+\gamma_4\right)$.

While $\left(\gamma_3+\gamma_4\right)$ is unobservable, it is closely related to strategic tax-setting reactions, which in concept are observable. Since equation (3) implies that $\frac{\partial \tau_i}{\partial \overline{\tau}}=\frac{\gamma_{3i}+\frac{\gamma_{4i}}{2}}{\gamma_{1i}+\gamma_{3i}+\gamma_{4i}}$, it follows that if $\hat{\gamma}_{3i}=\hat{\gamma}_{4i}=0$, then $\frac{\partial \tau_i}{\partial \overline{\tau}}$ takes the same value for all countries, and

(C1) $$\gamma_3+\gamma_4=\frac{\frac{\partial \tau_i}{\partial \overline{\tau}}}{\left(1-\frac{\partial \tau_i}{\partial \overline{\tau}}\right)}+\frac{\frac{\gamma_4}{2}}{\left(1-\frac{\partial \tau_i}{\partial \overline{\tau}}\right)}.$$

If $\frac{\partial \tau_i}{\partial \overline{\tau}}\geq 0$, so tax rates are not strategic substitutes, and assuming that $\frac{\partial \tau_i}{\partial \overline{\tau}}<1$,[26] then it follows from (C1) that $\left(\gamma_3+\gamma_4\right)\geq 0$ if $\gamma_4\geq -2\frac{\partial \tau_i}{\partial \overline{\tau}}$. This condition is clearly satisfied if $\gamma_4>0$; and it is also satisfied if γ_4 is negative but small in magnitude relative to $\frac{\partial \tau_i}{\partial \overline{\tau}}$. Recall that γ_4 is $\frac{\gamma_{4i}}{\gamma_{1i}}$, the ratio of the coefficient in equation (1) on the interaction between the deviation of actual and desired tax rates and the deviation of a country's tax rate from the world average to the coefficient on the squared deviation of a country's tax rate from its desired rate. It is reasonable to expect the perceived marginal cost of deviating from a preferred tax rate to increase much more with deviations from preferred rates than with deviations from world averages, in which case the magnitude of γ_{1i} will significantly exceed that of γ_{4i}, and make it very likely that $\gamma_4>-2\frac{\partial \tau_i}{\partial \overline{\tau}}$. Hence if tax rates are strategic complements then it is very likely that $\left(\gamma_3+\gamma_4\right)>0$.

---

[26] $\frac{\partial \tau_i}{\partial \overline{\tau}}<1$ is a common modeling restriction that rules out explosive solutions. Furthermore, equation (3) implies that $\frac{\partial \tau_i}{\partial \overline{\tau}}<1$ is a necessary condition for $\frac{\partial \tau_i}{\partial \tau_i^*}>0$.

A similar logic applies if $\frac{\partial \tau_i}{\partial \overline{\tau}} < 0$, so if tax rates are strategic substitutes, then it is very likely that $(\gamma_3 + \gamma_4) < 0$.

Appendix D

Section D.1 of this appendix considers the implications of harmonizing taxes at something other than the rate τ_h^* in (11) that maximizes collective objectives. Section D.2 considers the consequences of estimating σ^2 using tax rates measured with error.

D.1. Tax harmonization at rates other than τ_h^*.

If governments impose taxes at a harmonized rate $\tau_h = \tau_h^* + \varepsilon_h$, then from (10),

(D1) $$\frac{R(\tau_h) - S}{\sum \gamma_{1i}} = 2\left(\tau_h^* + \varepsilon_h\right)\tau_h^* - \left(\tau_h^* + \varepsilon_h\right)^2 - \sum\left(\tau_i - \overline{\tau}\right)^2 \frac{\left(\gamma_{1i} + \gamma_{3i} + \gamma_{3i}\right)}{\sum \gamma_{1i}} + \overline{\tau}^2 - 2\overline{\tau}\left(\tilde{\tau} + \Delta\right).$$

Equation (D1) differs from (10) only in the first two terms on the right side. Applying (D1) in place of (10), (12) becomes

(D2) $$\frac{R\left(\tau_h^* + \varepsilon_h\right) - S}{\sum \gamma_{1i}} = \left(\Delta + \tilde{\tau} - \overline{\tau}\right)^2 - \varepsilon_h^2 - \sum\left(\tau_i - \overline{\tau}\right)^2 \frac{\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right)w_i}{\sum \gamma_{1i} w_i},$$

which in turn implies that

(D3) $$\frac{R\left(\tau_h^* + \varepsilon_h\right) - S}{\sum \gamma_{1i} w_i} = \Delta^2 - \varepsilon_h^2 - \sigma^2 - \sum\left(\tau_i - \overline{\tau}\right)^2 \frac{\left(\gamma_{3i} + \gamma_{4i}\right)w_i}{\sum \gamma_{1i} w_i} - 2\Delta\left(\overline{\tau} - \tilde{\tau}\right).$$

Equation (D3) differs from (13) only in replacing Δ^2 with $\left(\Delta^2 - \varepsilon_h^2\right)$.

D.2. Estimating σ^2 *using tax rates measured with error.*

If tax rates are measured with error, $\tau_i = \tau_i^t + u_i$, in which τ_i^t is jurisdiction *i*'s true tax rate, and u_i a random measurement error with zero weighted mean, then the measured variance σ^2 is

(D4) $$\sigma^2 = \sum\left[\tau_i^t + u_i - \sum\left(\tau_i^t + u_i\right)\frac{\gamma_{1i}w_i}{\sum\gamma_{1i}w_i}\right]^2 \frac{\gamma_{1i}w_i}{\sum\gamma_{1i}w_i},$$

from which it follows that

(D5) $$\sigma^2 = \sum\left[\tau_i^t - \sum\tau_i^t \frac{\gamma_{1i}w_i}{\sum\gamma_{1i}w_i}\right]^2 \frac{\gamma_{1i}w_i}{\sum\gamma_{1i}w_i} + \sum u_i^2 \frac{\gamma_{1i}w_i}{\sum\gamma_{1i}w_i}.$$

The first term on the right side of (D5) is the true weighted variance of tax rates. Consequently, the measured variance of tax rates exceeds the true variance by the expected value of u_i^2, the expected squared measurement error.

Appendix E

This appendix considers the implications of replacing $O_i\left(\tau_i, d_i\right)$ with $O_i\left(\tau_i, d_i^{\rho}\right)$, with $d_i^{\rho} = \tau_i - \overline{\tau}_i$ and $\overline{\tau}_i = \sum_j \nu_j^i \tau_j$. In this specification, each country *i* uses its own idiosyncratic weights ν_j^i to construct a world average tax rate for comparison purposes, with $\sum_j \nu_j^i = 1, \forall i$. As a result, (3) becomes

(E1)
$$\tau_i = \frac{\left(\gamma_{1i} + \frac{\gamma_{4i}}{2}\right)\tau_i^* + \left(\gamma_{3i} + \frac{\gamma_{4i}}{2}\right)\overline{\tau}_i}{\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right)} - \frac{\frac{\gamma_{2i}}{2}}{\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right)},$$

and therefore, instead of (A3),

(E2)
$$\begin{aligned} O_i\left(\tau_i, d_i\right) &= O_i\left(\tau_i^*, 0\right) - \tau_i^{*2}\gamma_{1i} + \left(\tau_i - \overline{\tau}_i\right)^2\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right) - \overline{\tau}_i^2\gamma_{1i} + 2\overline{\tau}_i\tau_i\gamma_{1i} \\ &+ 2\frac{\overline{\tau}_i\left(\tau_i - \overline{\tau}_i\right)\left(\gamma_{3i} + \frac{\gamma_{4i}}{2}\right)\gamma_{1i}}{\gamma_{1i} + \frac{\gamma_{4i}}{2}} + \overline{\tau}_i\frac{\gamma_{2i}\gamma_{1i}}{\gamma_{1i} + \frac{\gamma_{4i}}{2}} \end{aligned}.$$

Applying (E2) in place of (A3), (7) becomes

(E3)
$$\begin{aligned} S &= \sum O_i\left(\tau_i^*, 0\right)w_i - \sum \tau_i^{*2}\gamma_{1i}w_i + \sum\left(\tau_i - \overline{\tau}_i\right)^2\left(\gamma_{1i} + \gamma_{3i} + \gamma_{4i}\right)w_i \\ &- \sum \overline{\tau}_i^2\gamma_{1i}w_i + 2\sum \overline{\tau}_i\tau_i\gamma_{1i}w_i + 2\Delta\breve{\tau}\sum\gamma_{1i}w_i + 2\sum\left(\tau_i^* - \tau_i\right)\left(\overline{\tau}_i - \breve{\tau}\right)\gamma_{1i}w_i \end{aligned},$$

in which $\breve{\tau} \equiv \frac{\sum \overline{\tau}_i\gamma_{1i}}{\sum\gamma_{1i}}$ is a weighted average of the $\overline{\tau}_i$ values.

With any harmonized tax rate τ_h, $\overline{\tau}_i = \tau_h$, so the use of d_i^{ρ} in place of d_i does not change equations (8) and (9). Together, (E3) and (9) imply that

$$
\text{(E4)} \quad \begin{aligned} \frac{R(\tau_h)-S}{\sum \gamma_{1i} w_i} &= 2\tau_h(\tilde{\tau}+\Delta)-\tau_h^2-\sum(\tau_i-\overline{\tau}_i)^2 \frac{(\gamma_{1i}+\gamma_{3i}+\gamma_{4i})w_i}{\sum \gamma_{1i} w_i}+\frac{\sum \overline{\tau}_i^2 \gamma_{1i} w_i}{\sum \gamma_{1i} w_i} \\ &-2\frac{\sum \overline{\tau}_i \tau_i \gamma_{1i} w_i}{\sum \gamma_{1i} w_i}-2\Delta\breve{\tau}-2\frac{\sum(\tau_i^*-\tau_i)(\overline{\tau}_i-\breve{\tau})\gamma_{1i} w_i}{\sum \gamma_{1i} w_i} \end{aligned} .
$$

Condition (11) for an efficient harmonized tax is unchanged by the appearance of d_i^ρ rather than d_i in the government's objective function. Applying (11), it follows from (E4) that for an efficient harmonized tax rate,

$$
\text{(E5)} \quad \frac{R(\tau_h^*)-S}{\sum \gamma_{1i} w_i} = \Delta^2-\sigma^2-\sum(\tau_i-\overline{\tau}_i)^2 \frac{(\gamma_{3i}+\gamma_{4i})w_i}{\sum \gamma_{1i} w_i}-2\Delta(\breve{\tau}-\tilde{\tau})-2\frac{\sum(\tau_i^*-\tau_i)(\overline{\tau}_i-\breve{\tau})\gamma_{1i} w_i}{\sum \gamma_{1i} w_i} .
$$

Applying (14a) and (14b) to (E5) produces

$$
\text{(E6)} \quad \begin{aligned} \frac{R(\tau_h^*)-S}{\sum \gamma_{1i} w_i} &= \Delta^2-(1+\gamma_3+\gamma_4)(\sigma^2+\breve{\xi})-(\gamma_3+\gamma_4)\left[\tilde{\tau}^2-2\frac{\sum \tau_i \overline{\tau}_i \gamma_{1i} w_i}{\sum \gamma_{1i} w_i}+\frac{\sum \overline{\tau}_i^2 \gamma_{1i} w_i}{\sum \gamma_{1i} w_i}\right] \\ &-2\Delta(\breve{\tau}-\tilde{\tau})-2\frac{\sum(\tau_i^*-\tau_i)(\overline{\tau}_i-\breve{\tau})\gamma_{1i} w_i}{\sum \gamma_{1i} w_i} \end{aligned} ,
$$

with $\breve{\xi} \equiv \dfrac{\sum(\tau_i-\overline{\tau}_i)^2(\hat{\gamma}_{3i}+\hat{\gamma}_{4i})\dfrac{\gamma_{1i} w_i}{\sum \gamma_{1i} w_i}}{1+\gamma_3+\gamma_4}$.

Collecting terms, (E6) implies

$$
\text{(E7)} \quad \begin{aligned} \frac{R(\tau_h^*)-S}{\sum \gamma_{1i} w_i} &= \Delta^2-(1+\gamma_3+\gamma_4)(\sigma^2+\breve{\xi})-(\gamma_3+\gamma_4)(\breve{\tau}-\tilde{\tau})^2-2\Delta(\breve{\tau}-\tilde{\tau}) \\ &-\frac{\sum\left[(\gamma_3+\gamma_4)\overline{\tau}_i+2\tau_i^*-2(1+\gamma_3+\gamma_4)\tau_i\right](\overline{\tau}_i-\breve{\tau})\gamma_{1i} w_i}{\sum \gamma_{1i} w_i} \end{aligned} .
$$

Applying (3), (14a), and (14b) to (E7),

$$\text{(E8)}\quad \begin{aligned}\frac{R\left(\tau_h^*\right)-S}{\sum \gamma_{1i} w_i} &= \Delta^2-\left(1+\gamma_3+\gamma_4\right)\left(\sigma^2+\breve{\xi}\right)-\left(\gamma_3+\gamma_4\right)\left(\breve{\tau}-\tilde{\tau}\right)^2-2\Delta\left(\breve{\tau}-\tilde{\tau}\right) \\ &+\frac{\sum\left[\gamma_3\bar{\tau}_i+\gamma_4\frac{\tau_i^*}{\gamma_{1i}}+\frac{\gamma_{2i}}{\gamma_{1i}}+2\left(\hat{\gamma}_{3i}+\hat{\gamma}_{4i}\right)\left(\bar{\tau}_i-\tau_i\right)-\hat{\gamma}_{4i}\bar{\tau}_i\right]\left(\bar{\tau}_i-\breve{\tau}\right)\gamma_{1i}w_i}{\sum \gamma_{1i} w_i}\end{aligned}.$$

Equation (E8) is very similar in form to equation (15). The first line of (E8) is identical to (15), with the ξ replaced by $\breve{\xi}$, and $\bar{\tau}$ replaced by $\breve{\tau}$. The second line of (E8) introduces adjustments: since $\breve{\tau}=\frac{\sum \bar{\tau}_i \gamma_{1i}}{\sum \gamma_{1i}}$, the second line of (E8) is the sum of the covariances of the bracketed terms with $\bar{\tau}_i$. There is little reason to expect $\frac{\tau_i^*}{\gamma_{1i}}$ to covary with $\bar{\tau}_i$, since potential competition does not affect objective-maximizing tax rates in the absence of competition; and while $\frac{\gamma_{2i}}{\gamma_{1i}}$ might covary with $\bar{\tau}_i$ (e.g., because governments perceive different costs and benefits of deviating from relevant world average tax rates depending on levels of the averages), it is unclear even what sign this covariance might take. Taking these two covariances, and the $\hat{\gamma}_{3i}$ and $\hat{\gamma}_{4i}$ parameters in (E8), all to be small enough to be safely ignored, (E8) becomes

$$\text{(E9)}\quad \frac{R\left(\tau_h^*\right)-S}{\sum \gamma_{1i} w_i}=\Delta^2-\left(1+\gamma_3+\gamma_4\right)\left(\sigma^2+\breve{\xi}\right)-\left(\gamma_3+\gamma_4\right)\left(\breve{\tau}-\tilde{\tau}\right)^2-2\Delta\left(\breve{\tau}-\tilde{\tau}\right)+\gamma_3\sigma_{\bar{\tau}_i}^2,$$

in which $\sigma_{\bar{\tau}_i}^2 \equiv \frac{\sum\left(\bar{\tau}_i-\breve{\tau}\right)^2 \gamma_{1i} w_i}{\sum \gamma_{1i} w_i}$ is the variance of idiosyncratic average tax rates. It follows from (E9) that $\gamma_3>0$ implies that greater dispersion in the values of $\bar{\tau}_i$ increases the likelihood that efficient tax harmonization advances government objectives; and the opposite is the case if $\gamma_3<0$. Since positive values of γ_3 are generally associated with strategic complementarity, it follows that if tax rates are strategic complements then greater idiosyncratic variation in $\bar{\tau}_i$ broadens the range of cases in which harmonization would advance collective objectives.

Appendix F

This appendix considers the implications of replacing $O_i(\tau_i, d_i)$ with $O_i(\tau_i, \mathbf{d_i})$, and therefore (1) with (18). Expanding equation (18),

(F1)
$$\begin{aligned} O_i(\tau_i, \mathbf{d_i}) &= O_i(\tau_i^*, \mathbf{0}) - (\tau_i - \tau_i^*)^2 \gamma_{1i} - \left[\tau_i - \sum_j \tau_j \nu_j\right]\gamma_{2i} \\ &- \left[\tau_i^2 - 2\tau_i \sum_j \tau_j \nu_j + \sum_j \tau_j^2 \nu_j\right]\gamma_{3i} - (\tau_i - \tau_i^*)\left[\tau_i - \sum_j \tau_j \nu_j\right]\gamma_{4i} \end{aligned}.$$

Differentiating the right side of (F1) with respect to τ_i yields

(F2)
$$2\gamma_{1i}(\tau_i^* - \tau_i) - \gamma_{2i} + 2\gamma_{3i}\left(\sum_j \tau_j \nu_j - \tau_i\right) + \gamma_{4i}\left(\sum_j \tau_j \nu_j + \tau_i^* - 2\tau_i\right).$$

Imposing $\sum_j \tau_j \nu_j = \overline{\tau}$, (F2) is identical to (2), and therefore (F2) implies (3) and (A1), so the tax rates that countries choose to maximize (18) are the same as those they choose to maximize (1) – and as a result, tax rate choices cannot distinguish these models.

Equations (18) and (A1) together imply that

(F3)
$$\begin{aligned} O_i(\tau_i, \mathbf{d_i}) &= O_i(\tau_i^*, \mathbf{0}) - \tau_i^{*2}\gamma_{1i} - \tau_i^2\gamma_{1i} + 2\tau_i^2\gamma_{1i} + 2\frac{\tau_i\left[(\tau_i - \overline{\tau})\left(\gamma_{3i} + \frac{\gamma_{4i}}{2}\right) + \frac{\gamma_{2i}}{2}\right]\gamma_{1i}}{\gamma_{1i} + \frac{\gamma_{4i}}{2}} \\ &- (\tau_i - \overline{\tau})\gamma_{2i} - (\tau_i - \overline{\tau})^2\gamma_{3i} - \sum_j (\tau_j - \overline{\tau})^2 \nu_j \gamma_{3i} + \frac{(\tau_i - \overline{\tau})\left[(\tau_i - \overline{\tau})\left(\gamma_{3i} + \frac{\gamma_{4i}}{2}\right) + \frac{\gamma_{2i}}{2}\right]\gamma_{4i}}{\gamma_{1i} + \frac{\gamma_{4i}}{2}} \end{aligned}.$$

Equation (F3) differs from (A2) only in the inclusion of the $\sum_j (\tau_j - \overline{\tau})^2 \nu_j \gamma_{3i}$ term, so

(F4)
$$O_i(\tau_i, \mathbf{d_i}) = O_i(\tau_i, d_i) - \sum_j (\tau_j - \overline{\tau})^2 \nu_j \gamma_{3i}.$$

Equation (F4) implies that using $O_i(\tau_i, \mathbf{d_i})$ in place of $O_i(\tau_i, d_i)$ changes (13) to

$$\text{(F5)}\qquad \frac{R\left(\tau_h^*\right)-S}{\sum \gamma_{1i}w_i} = \Delta^2 - \sigma^2 - \sum\left(\tau_i - \overline{\tau}\right)^2 \frac{\left\{\left[\frac{\gamma_{3i}w_i}{\sum \gamma_{3i}w_i} - v_i\right]\sum \gamma_{3i}w_i + \gamma_{4i}w_i\right\}}{\sum \gamma_{1i}w_i} - 2\Delta\left(\overline{\tau} - \tilde{\tau}\right),$$

which is identical to (13), other than replacing $-\sum\left(\tau_i - \overline{\tau}\right)^2 \frac{\gamma_{3i}w_i}{\sum \gamma_{1i}w_i}$ on the right side with

$$-\sum\left(\tau_i - \overline{\tau}\right)^2 \frac{\left[\frac{\gamma_{3i}w_i}{\sum \gamma_{3i}w_i} - v_i\right]\sum \gamma_{3i}w_i}{\sum \gamma_{1i}w_i}.$$

Appendix G

Table G1
Tax Competition Critical Values $\left(\tilde{\Delta}\right)$, Effective Average Tax Rates

Year	**Population statistics**		$\tilde{\Delta}$ **values** ν_i *weights*				
γ_{1i} *weights*	$\tilde{\tau}$	σ	**GDP**	**Pop**	**Unw**	**Havens**	**0**
2020							
GDP	24.49	5.34	5.34	4.39	2.25	1.45	0.58
Population	23.43	5.93	7.09	5.93	3.08	1.95	0.74
Unweighted	19.26	5.63	12.91	11.18	5.63	2.97	0.81
2010							
GDP	27.11	4.80	4.80	3.67	1.67	1.03	0.42
Population	25.81	5.98	7.43	5.98	2.88	1.76	0.68
Unweighted	21.04	6.68	15.10	12.97	6.68	3.53	1.03
2000							
GDP	33.19	5.72	5.72	4.55	2.34	0.91	0.49
Population	31.88	6.09	7.54	6.09	3.08	1.11	0.58
Unweighted	27.38	6.50	14.53	12.41	6.50	1.69	0.76

Note to Table G1: the table presents critical values $\left(\tilde{\Delta}\right)$ of the impact of tax competition, performing the calculations of Table 2 using effective average corporate tax rates rather than statutory tax rates. The sample is a balanced panel of 28 countries for which it is possible to obtain effective average tax rate data for 2000, 2010, and 2020.

Table G2
Tax Competition Critical Values $\left(\tilde{\Delta}\right)$, Statutory Rates, EATR Sample

Year	**Population statistics**				$\tilde{\Delta}$ **values** ν_i *weights*		
γ_{1i} *weights*	$\tilde{\tau}$	σ	**GDP**	**Pop**	**Unw**	**Havens**	**0**
2020							
GDP	25.35	5.46	5.46	4.63	2.78	1.33	0.58
Population	24.44	5.90	6.88	5.90	3.58	1.66	0.70
Unweighted	21.38	6.49	11.58	10.25	6.49	2.67	0.96
2010							
GDP	28.80	4.70	4.70	3.46	1.68	0.82	0.38
Population	27.34	5.88	7.52	5.88	2.99	1.40	0.62
Unweighted	23.05	7.15	14.93	12.63	7.15	2.90	1.08
2000							
GDP	38.61	8.16	8.16	6.79	4.10	2.60	0.85
Population	37.11	8.06	9.70	8.06	4.69	2.85	0.87
Unweighted	32.53	6.72	15.14	12.71	6.72	3.22	0.69

Note to Table G2: the table presents critical values $\left(\tilde{\Delta}\right)$ of the impact of tax competition, performing the calculations of Table 2 using statutory corporate tax rates. The sample is the balanced panel of 28 countries analyzed in the calculations reported in Table G1.