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Pareto-Improving Minimum Corporate Taxation

Abstract

The recent international agreement on a minimum effective corporate tax rate marks a profound change in global tax arrangements. The appropriate level of that minimum, however, has been, and remains, extremely contentious. This paper explores the strategic responses to a minimum tax, which—the policy objective being to change the rules of tax competition game—are critical for assessing the design and welfare impact of, and prospects for, this fundamental policy innovation. Analysis and calibration plausibly suggest sizable scope for minima that are Pareto-improving, benefiting low tax countries as well as high tax, relative to the uncoordinated equilibrium.

JEL-Codes: H210, H250, F230.

Keywords: tax competition, minimum taxation, corporate tax reform, international taxation.

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1 Introduction

For decades, proposals to limit international corporate tax competition by agreeing on some common minimum effective tax rate have had virtually no practical traction.[1] In October 2021, however, 136 members of the G-20/OECD-led 'Inclusive Framework' agreed to establish a minimum effective corporate tax rate of 15%.[2] This is a profound change to the century-old international corporate tax architecture, and a pathbreaking innovation in global tax policies more generally.[3] The appropriate level of the minimum rate, however, has been—and is sure to remain—extremely contentious. Some countries, and much of civil society, argue forcefully that 15% is far too low. In contrast, and unsurprisingly, many traditionally low tax countries—notably Ireland, which, with a statutory rate of 12.5%, has played a pivotal role in the discussions—have expressed forceful reservations. Their doubts are understandable. Low tax countries, confronted by an externally-imposed increase in effective tax rates on profits booked there, face a trade-off: between, on one hand, a loss from reduced inward profit shifting[4] and, on the other, a potential revenue gain if they were to raise their rate to the minimum level (albeit on a base reduced by diminished profit shifting).[5] While this trade off is evidently important for low tax countries to consider, it is clear that most firmly expect to lose from adoption of a global minimum rate. That, indeed, appears to be the popular perception of the impact of the minimum: that low tax countries, being forced to set a higher rate than they have they chosen when unconstrained in looking to their own interests, must, as a result, be losers. But there is more to the issue than that.

Assessing the welfare implications for a low tax country of a binding minimum effective rate imposed upon it ultimately requires considering more than the essentially static trade off just mentioned. It requires moving beyond the commonplace (usually implicit) presumption in the policy debate that a minimum tax will not change the tax-setting behavior of high tax countries

[1]Outside the academic literature, the most prominent proposals have been in Europe, dating back to the recommendation in Neumark (1962) of a 50% minimum and continuing with that of Ruding (1992) of a 30% minimum. Only in the African regional trading blocs WAEMU and CEMAC have minima been established.

[2]This is 'Pillar Two' of a wider package: see OECD (2021a)

[3]Agreement does not oblige a member to impose the minimum, but does oblige it to accept imposition by others even on earnings in that country.

[4]OECD (2020) (para. 256) estimates that a minimum rate of 12.5% might reduce profits booked in investment hubs by around 10 percent; that excludes multinationals parented in the United States, for which Clausing (2020) suggests that the minimum tax-like features of the 2017 U.S. 'GILTI' provisions—which, roughly, impose a minimum tax of 10.5-13.125% on U.S. affiliates' earnings abroad—might ultimately reduce the corporate tax base of low tax jurisdictions by 12-16% (and almost double that if the minimum were to be applied globally rather than per country).

[5]Abstracting from reduced profit shifting, Devereux et al. (2020) (Table 2.3) put the additional revenue raised in each low tax country as a result of a 10% minimum tax at 5-10% of the profits of foreign affiliates present there; for a 12.5% minimum, and allowing for reduced profit shifting, OECD (2020) puts the revenue gain at around 0.3% of global corporate tax revenue (Table 3.13, again excluding affiliates of U.S. parents).

that it does not directly constrain—which precludes any spillback effects on the low tax countries that it does constrain. The purpose of the minimum, after all, is precisely to alter the rules of the tax competition game. Understanding the nature, extent and consequences of the induced impact of a minimum tax on the outcome of tax competition must thus be central to assessing its efficiency and welfare effects. What those strategic effects will be, however, is far from clear. The aim of this paper is to explore and elucidate them.

Previous work has established, in general terms, that a low tax country may indeed benefit from a minimum that obliges it to raise its own rate, as a result of spillback from increased rates in high tax countries. The aim here is to go further and ask, both as a matter of theory and with an eye to current and prospective international agreement: How high a minimum rate would the low country most prefer? And how high can the minimum be set while still leaving not only the high but also the low tax country better off than in the uncoordinated equilibrium?[6]

More precisely, we characterize, in the base case of a two-country Nash game two critical levels of the minimum rate. (The model itself is an extension of that in Kanbur and Keen (1993)). The first level is that which is most preferred by the low tax country: this, with the high tax country always gaining from an increase in the minimum, is the *Pareto efficient minimum rate*. The second is the highest level of the minimum which, while not its most preferred, is for the low tax country welfare-superior to the uncoordinated equilibrium: this is the *maximal Pareto dominant rate*. Having characterized both critical levels of the minimum rate, we further show that each can be expressed as a simple transform of the tax rate set in the uncoordinated equilibrium by the low tax country—a convenient property that we exploit to numerically gauge the scope for mutual gain from minimum rates even higher than now currently agreed. The Paretian standard being applied is is of course a far more demanding welfare standard than simply seeking some increase in collective efficiency: We nonetheless remark on this case below. But, with no prospect of high tax countries making transfers to low tax ones, it is also a more obviously policy relevant one.

Section 2 motivates and develops a model of tax competition tractable enough for these purposes, and sets out the uncoordinated (Nash) equilibrium. The main results are in Section 3, which discusses and characterizes the Pareto efficient and maximally dominant minimum rates, reports

[6] Two recent papers each take a different perspective on minimum corporate taxation. Hines (2022) explores the implications for collective efficiency: potential Pareto efficiency, that is, rather than actual. We take up this issue below. In Johannesen (2022), the lowest tax countries set a rate of zero in the uncoordinated equilibrium. They are then sure to benefit from any minimum that leaves some profit shifting in place, because they then raise at least some revenue. In practice (and perhaps reflecting location-specific rents associated with time zone, treaty network, and the like) many low tax countries derive strictly positive revenue, including through fees and various charges (or derive other benefit), in an amount that increases with the extent of inward profit shifting and so reflects the considerations set out below.

simulations, and briefly considers extension to the three-country case and to a perspective of collective welfare. Section 4 concludes.[7]

2 Tax Competition with Profit Shifting

2.1 Preliminaries

The framework now set out inevitably abstracts from much detail of the 2021 Inclusive Framework agreement. In particular, we assume that the minimum is levied by the source rather than by the residence country.[8] This may appear to run counter to the rule order originally envisaged in the policy discussions, which gives primacy to an 'Income Inclusion Rule' (topping up to the minimum by the residence country) over an 'Undertaxed Payments Rule' (topping up at source). Source countries, however, have a strong incentive to preempt a foreign government's imposition of a minimum rate by imposing that minimum itself: this has no impact on the investor but transfers revenue to itself.[9] This possibility, stressed in OECD (2020) and Devereux et al. (2020), was made real by Ireland's announcement that it would respond to the 15% minimum by raising its own rate to that level.[10] And—doubtless recognizing these realities—the recently issued model rules for the minimum explicitly provide for the source country to apply a 'top up' tax of this kind.[11]

Three other features of the model deserve highlighting. First, we assume for the most part that there are only two (asymmetric) countries; throughout the paper, that setting the lower tax rate, t, is indicated by lower case letters, that setting the higher, T, by upper case; welfare of the former is thus $w(t, T)$, and of the latter is $W(T, t)$. (A three country extension is considered briefly at the end of the next section).

Second, we set aside tax effects on real investment. Tax competition is thus taken to be for 'paper' profits rather than real activity, and, moreover, we set aside the possibility that profit shifting opportunities may, by reducing the cost of capital, in themselves encourage real investment: strong evidence for which is provided by, for example, Suárez Sorrato (2018) and surveyed in Klemm and Liu (2021). There is now indeed emerging interest in the investment effects of minimum corporate

[7] An online appendix (attached below) provides further detail on the derivations.

[8] We also set aside the less than global scope of the agreement (in terms of both countries and multinationals) and its exclusion of a modest substance-based return.

[9] The logic is the same as that behind the standard prescription that a source country attracting capital from one offering a credit system set its rate equal to that in the latter: see for example Gordon (1992).

[10] For those multinationals in scope of the the minimum.

[11] This is the 'Qualified 'Domestic Minimum Top Up Tax': see OECD (2021b).

taxation.[12] But it is a concern with competition for paper profit that has been at the heart of the policy discussions, and on which we focus here. In this case it is plausible to suppose (and will be verified in the model below) that each country benefits from an increase in the tax rate of the other: the low tax country because that increases inward profit-shifting, the high tax because it reduces profit shifting.[13]

Third, countries are assumed to play Nash. The leading alternative would be to assume a first mover. In this case, it is straightforward to see that, strikingly, the low tax country, whether it follows or leads, loses from the imposition of a minimum tax just above the rate it sets in the uncoordinated equilibrium.[14] Which approach better represents reality is certainly arguable, but the Nash case seems at least as plausible and important to explore.[15]

An immediate implication of these three features, using the envelope property that[16] $w_t(t^N, T^N) = W_T(T^N, t^N) = 0$, is that the imposition of a minimum infinitesimally above the lower tax rate in the uncoordinated Nash equilibrium, t^N, is sure to benefit the high tax country (since $dW = W_t.dt$), and also benefits the low tax country (since $dw = dW_T.(dT/dt)$) if (and only if) tax rates are strategic complements for the high tax country, in the sense that its best response to a higher rate in the low tax country is to raise its own rate. Strategic complementarity is perhaps the more instinctive and commonplace assumption, but is not theoretically assured. Vrijburg and de Mooij (2016), in particular, show that the response to a tax increase abroad, leading to an inflow of investment and hence an increase in domestic revenue, may to be reduce the domestic tax rate if the degree of substitutability between the domestic public good and private consumption is sufficiently low. Empirically, however, the weight of evidence suggests that statutory corporate tax rates—the most

[12]See for example Hanappi and Cabral (2020), which suggests the effects to be modest.

[13]Real investment effects can mean, for instance, that the spillover effect of a tax increase elsewhere is adverse. Take, for example, the seminal model of tax competition with mobile real capital of Zodrow and Mieszkowski (1986) and Wilson (1986). If the low tax country is a capital exporter, then an increased tax rate abroad will tend to depress the global demand for capital and so reduce its pre-tax return earnings, and, hence, welfare. See also Peralta and van Ypersele (2006), which analyses minimum taxation in a model without profit shifting.

[14]If the high tax country is the leader, then setting a minimum rate just above that initially set by the low tax country will lead the high tax country to reduce its rate (since it is now sure that any further reduction in its own rate will not be met by a reduction in the low country's rate); so the spillover effect on the low tax country—the only first order effect on its welfare, since it is setting its best response to the high tax rate—acts to reduce its welfare. (Konrad (2009) notes that this can also be the case with a minimum set strictly below the lowest initial rate.) If, on the other hand, it is the low tax country that leads, then by selecting its preferred point on the best response of the high tax country it is in effect already picking its preferred minimum rate; so the introduction of some formal minimum—which places the outcome at the corresponding point on the high tax country's best response—can never make it better off. See Wang (1999) and Keen and Konrad (2013).

[15]Further possibilities arise in a repeated game context—Kiss (2012), for example, shows that imposing a minimum can make a cooperative outcome less sustainable (by reducing the punishment from defection)—but do not seem central to the issues at hand here.

[16]Derivatives are indicated by a prime for functions of a single variable, and by subscripts for functions of several.

relevant for profit shifting concerns—are strategic complements: see the reviews in Brueckner (2003), Leibrecht and Hocgatterer (2012) and OECD (2020).[17] The magnitude of the effect, however, has not been tied down with precision. Devereux et al. (2008), for example, estimate, for a sample of advanced countries, that a one percentage point cut in the average foreign statutory rate lowers the home rate by 0.34-0.67 percentage points; in a sample that includes developing countries, Crivelli et al. (2016) find a somewhat lower but nonetheless significant response of 0.25-0.3 points.

While suggestive, the result that an infinitesimally binding minimum is Pareto-improving is hardly enough for policymaking and assessment.[18] Rather it leads to the two questions above: What is the Pareto efficient level of the minimum tax rate, beyond which further increases will reduce welfare in the low tax country? And how high can the minimum be set and still leave the low tax country better off than in the uncoordinated equilibrium?

2.2 The Uncoordinated Nash Equilibrium

We address these questions using an extension of Kanbur and Keen (1993), the extensions being in the application to profit shifting rather than cross-border shopping and in allowing policymakers to care about not only tax revenue but also private income.[19] The two countries thus differ not only in 'size' but also in their taste for public spending. We proceed by assuming that the lower case country sets the lower tax rate in equilibrium, then constructively establishing conditions for the existence of, and characterizing, a unique Nash equilibrium in which that is indeed the case.

The representative citizen-multinational of each country[20] earns a fixed amount of pre-tax profit, π and Π (both strictly positive). These may, however, be declared for tax purposes in either country. The net profit of the multinational located in the high tax country is thus $(1 - ts - T(1 - s) - C(s))\Pi$, where s denotes the proportion of profit shifted to the low tax country and $C(s)\Pi$ is the (non-

[17] While some empirical studies find strategic substitutability, this seems to arise mainly in the quite different context of tax competition across subnational governments. Buettner and Poehnlein (2021), for instance, find that high tax municipalities in Germany responded to binding minima imposed on neighbors by lowering their business tax rate, while Lyytikäinen (2012) finds no significant interaction in property tax rates across Finnish municipalities. Both settings are quite different—respectively, in the even greater disconnect between residents and firm ownership at municipal level, and relative immobility of the base—from that of profit shifting across national borders. Agrawal et al. (2020) discuss the distinct considerations that shape best responses in tax interactions between local governments.

[18] Kanbur and Keen (1993) derive the stronger result that any minimum between the two Nash rates is Pareto-improving (Proposition 12); but this, as will be seen, is not the case in the extended version of their model used here.

[19] That the Kanbur and Keen (1993) structure can be reinterpreted as one of tax competition over profit shifted between revenue-maximizing governments is noted by Keen and Konrad (2013) and Agrawal and Wildasin (2020); this corresponds, in the notation introduced below, to the special case here in which $\lambda, \Lambda \to \infty$ and $\theta < 1$. Another precursor of the extension here is Nielsen (2002), which generalized the original setting to one of welfare maximization.

[20] For simplicity, we abstract here from the reality of extensive cross-border ownership: even in the U.S., around one-quarter of the domestic capital stock may be owned by foreign investors (Rosenthal and Austin (2016)).

deductible) cost of that shifting. Taking $C(s) = (\delta/2)s^2$, with $\delta > 0$ parameterizing those costs, maximizing with respect to s implies that profits will be shifted (only) out of the high tax country in amount $s = (T - t)\Pi/\delta$. The shifting costs incurred by the multinational in the high tax country are thus $(T - t)^2\Pi/2\delta$.

Welfare in each country is the sum of private after-tax income and tax revenue, the latter weighted by a fixed marginal valuation of public spending: λ in the low tax country, Λ in the high, and in each case strictly greater than unity. For the low tax country, which is the recipient of profit shifting, welfare is thus

$$w(t, T) = (1 - t)\pi + \lambda t \left(\pi + \left(\frac{T - t}{\delta} \right) \Pi \right). \tag{1}$$

The first term here is the after-tax income received by the resident shareholder, to which is added the social value of tax revenue; the latter in turn comes from both the profits of the resident multinational and those profits $s\Pi$ shifted into the low tax country from the high. Differentiating with respect to t gives

$$w_t(t, T)\delta/\Pi = (\lambda - 1)\delta\theta + \lambda T - \lambda 2t, \tag{2}$$

where $\theta \equiv \pi/\Pi$ is the ratio of the pre-tax profits accruing to the residents of the two jurisdictions, and so serves as an indicator of relative size. Differentiating again, $w_{tt}\delta/\Pi = -\lambda 2 < 0$. The second order condition is thus satisfiued and, all else equal, a discrete forced increase in the tax rate set by the low tax country above its level in any Nash equilibrium thus reduces its welfare—consistent with the popular view, set out in the Introduction, that a binding minimum is adverse to their interests. The key point here, however, is that all else will generally not be equal, because the high tax country can be expected to respond to an increase in the low rate.

Setting $w_t = 0$ in (2) and rearranging gives the best response of the low tax country to the rate in the high tax country as

$$t(T) = \frac{1}{2} \left[\left(\frac{\lambda - 1}{\lambda} \right) \delta\theta + T \right]. \tag{3}$$

Note too that $w_T(t, T) = (\lambda t \Pi)\delta > 0$: unsurprisingly, and as asserted above, the spillover effect for the low tax country of a rate increase abroad is strictly positive, reflecting the revenue it gains from the consequent increase in inward profit shifting.

The corresponding expression for the welfare of the high tax country is made a little more involved by outward profit shifting:

$$W(T,t) = \Pi - T\left(1 - \left(\frac{T-t}{\delta}\right)\right)\Pi - t\left(\frac{T-t}{\delta}\right)\Pi - \left(\frac{1}{2}\right)\frac{(T-t)^2}{\delta}\Pi + \Lambda T\left(1 - \left(\frac{T-t}{\delta}\right)\right)\Pi. \quad (4)$$

Here, the first four terms give after-tax income, recognizing that only un-shifted profits are taxed at the high tax rate (the second term), the rest being taxed in the low tax country (the third term), and that shifting profit incurs the costs characterized above (the fourth term). The final term reflects the collection of revenue by the high tax country from only un-shifted profit. Combining the first four terms in (4) gives

$$W(T,t) = (1-T)\Pi + \left(\frac{1}{2}\right)\frac{(T-t)^2}{\delta}\Pi + \Lambda T\left(1 - \left(\frac{T-t}{\delta}\right)\right)\Pi, \quad (5)$$

with the second term capturing the private gain from profit shifting net of the cost incurred in doing so. There are signs, however, of a political and social aversion to tax avoidance—especially in recent years, by multinationals—that might translate into this private gain being valued less highly than other forms of private income; an issue similar to that which arises, albeit in more extreme form, in the analysis of tax evasion.[21] The difference that avoidance is (at least can be) legal, whereas evasion, by definition, is illegal, is often hazy in practice and in any case does not seem wholly decisive in framing public attitudes or even policies. The popular terms 'tax dodging' and 'illicit financing' conflate the two. There is indeed evidence of strong general public disapprobation of tax avoidance. In a survey reported by HMRC (2015), for example, 61% of respondents felt that tax avoidance is never acceptable, while Scarpa and Signori (2020) conclude from their review of the evidence that "...tax avoidance is widely perceived at least as a morally doubtful practice". Certainly a marked and vociferous public discontent with tax avoidance by multinationals has been among the factors shaping the evolution of G-20/OECD-led Base Erosion and Profit Shifting project—the culmination of which is the 2021 agreement. One very direct and explicit indication of policymakers' disapproval is that several countries denied pandemic-related support not to profitable companies in general but specifically to those substantially present in low tax jurisdictions.

To allow for the possibility of such discounting of the private gain from profit shifting, we generalize (5) by replacing the 1/2 in the second term by a parameter α, so taking welfare in the high tax country to be

[21] As discussed, for instance, in Cowell (1990), Chapter 7.

$$W(T,t) = (1-T)\Pi + \alpha\frac{(T-t)^2}{\delta}\Pi + \Lambda T\left(1 - \left(\frac{T-t}{\delta}\right)\right)\Pi, \tag{6}$$

where $\alpha \in (0, 1/2)$. The two limiting values of α correspond to either full ($\alpha = 1/2$) or zero ($\alpha = 0$) social valuation of the net private gain from profit shifting.[22]

Differentiating in (6), the necessary condition on the maximizing choice of T implies that

$$W_T(T,t)\delta/\Pi = (\Lambda - 1)\delta + t(\Lambda - 2\alpha) + 2T(\alpha - \Lambda) = 0, \tag{7}$$

which, rearranged, gives the best response of the high tax country as

$$T(t) = \frac{1}{2}\left[\left(\frac{\Lambda - 1}{\Lambda - \alpha}\right)\delta + \left(\frac{\Lambda - 2\alpha}{\Lambda - \alpha}\right)t\right]. \tag{8}$$

This best response is readily seen to be shifted upwards by an increase in either Λ or[23] α. The former is as one would expect. The latter arises because a higher valuation of the private gain from profit shifting implies a greater willingness to accept the increase in such shifting that is induced by raising T.

From (8), the slope of the best response of the high tax country is given by $T'(t) = (\Lambda - 2\alpha)/2(\Lambda - \alpha) \geq 0$: consistent with the empirical evidence, tax rates are strategic complements for the high tax country. Differentiating $T'(t)$ shows, unsurprisingly, that a higher marginal valuation of revenue Λ leads to a steeper best response. A higher α, in contrast, while also shifting the best response of the high tax country upwards, flattens it. This comes from the convexity of the private gain from profit shifting in the tax difference $T - t$. As a consequence, the private gain from the increased profit shifting induced by increasing T is lower the higher is t, leading to a flatter best response; and that has a stronger impact in dulling the high tax country's response the greater is the weight α it attaches to this private gain. The implication is that a greater acceptance of profit shifting reduces the responsiveness of the high tax country to a minimum-induced increase in that of the low tax country, which dampens the spillback gain enjoyed by the latter. This will be important later. So too will be the implication of (8) that $T'(t) < 1$: the high tax country increases

[22] Other possibilities are conceivable. It might be, for example, that the private costs of shifting are simply transfers of rent (perhaps to tax advisors), and so create no social cost. Indeed if they are entirely transfers, so that the penultimate term in (4) vanishes, it can be shown that tax rates are strategic substitutes for the high tax country. Given, however, the weight of evidence supporting strategic complementarity between national corporate tax rates, we do not pursue this possibility.

[23] The claim here regarding α requires that $t < (\Lambda - 1)\delta/\Lambda$; but without this, it will be seen around (15) below, the questions at issue become vacuous, in that any minimum which constrains the low tax country also constrains the high.

its rate less than one-for-one in response to an increase in the rate set by the low tax country.

Note too that the spillover term W_t has the sign of $(\Lambda - 2\alpha)t + 2\alpha t$: as also asserted above, the high tax country thus always gains from an increase in the rate in the low tax country.

With these elements, the characterization of the uncoordinated Nash equilibrium—the benchmark against which the impact of partial coordination through a minimum rate is to be assessed—is straightforward:

Proposition 1. *If*

$$\frac{\Lambda - 1}{\Lambda} > \left(\frac{\lambda - 1}{\lambda}\right)\theta \tag{9}$$

then there exists a single Nash equilibrium in which $t^N < T^N$, with[24]

$$t^N = \delta\left(\frac{\Lambda - \alpha}{3\Lambda - 2\alpha}\right)\left[\left(\frac{\lambda - 1}{\lambda}\right)2\theta + \left(\frac{\Lambda - 1}{\Lambda - \alpha}\right)\right], \tag{10}$$

and

$$T^N = \frac{\delta}{2}\left[\frac{\Lambda - 1}{\Lambda - \alpha} + \left(\frac{\Lambda - 2\alpha}{3\Lambda - 2\alpha}\right)\left(\frac{\lambda - 1}{\lambda}\right)2\theta + \frac{\Lambda - 1}{3\Lambda - 2\alpha}\right]. \tag{11}$$

Proof. Substituting (8) into (3) and rearranging gives (10); substituting (10) into (8) then gives (11). Subtracting t^N from $T(t^N)$ in (8), collecting terms and substituting from (10), some rearrangement produces

$$\frac{T^N - t^N}{\delta} = \left(\frac{\Lambda}{3\Lambda - 2\alpha}\right)\left(\frac{\Lambda - 1}{\Lambda} - \frac{\lambda - 1}{\lambda}\theta\right), \tag{12}$$

from which (9) follows. □

The condition in (9) implies, as one would expect, that the country which sets the lower tax rate in equilibrium is marked by a relatively small share of global profits—a size effect familiar in models of tax competition—and/or by a relatively low marginal valuation of public spending. The comparative statics of the Nash rates themselves are also mostly straightforward: both are increasing in each of the marginal valuations Λ and λ and decreasing in θ. Less familiar, of course, is that they are also both increasing in α:[25] a higher social value attached to outward profit shifting by the high tax country leads it to increase its tax rate, which in turn induces a higher rate in the low tax country.

[24]When both governments maximize revenue ($\lambda, \Lambda \to \infty$) and $\theta < 1$ (satisfying (9)), equation (10) reduces to $t^N = \delta(1 + 2\theta)/3$; which is as in Proposition 1 of Kanbur and Keen (1993).

[25]This is most easily seen by recalling that a higher α shifts the best response of the high tax country upward while, from (3), having no impact on that of the low tax country.

3 Implications of a Minimum Rate

Suppose now the constraint is imposed that no tax rate may be set below some $\mu > t^N$, binding the country that sets the lower tax rate in the unconstrained Nash equilibrium and inducing the high tax country to then set its best response $T(\mu)$. Setting aside a complication returned to later, suppose too that the minimum is not so high as also to constrain the high tax country (so that $T(\mu) > \mu$).

3.1 Analysis

The implications for the high tax country are straightforward. Since (as seen above) it always benefits from an increase in the low tax rate, it prefers the highest possible minimum rate.

Things are more involved in the low tax country, whose welfare in the presence of the minimum, from (1), is now

$$w(\mu)\delta/\Pi = [1 + (\lambda - 1)\mu]\delta\theta + \lambda\mu(T(\mu) - \mu). \tag{13}$$

Differentiating, the impact of a higher minimum is thus given by

$$w'(\mu)\delta/\Pi = (\lambda - 1)\delta\theta + \lambda(T(\mu) - \mu)) + \lambda\mu(T' - 1). \tag{14}$$

Each of the first two effects on the right of (14) is strictly positive: a gain from higher taxation of the domestic tax base, and a gain from increased tax receipts from the profits initially shifted inwards. Recalling that $T' < 1$, the third, however, is negative: since the high tax country increases its rate by less than any increase in the minimum, the extent of profit shifting (proportional to the differential $T - t$) falls—which is a source of welfare loss for the low tax country.

How these effects play out is illustrated in Figure 1. This reflects the quadratic structure of $w(\mu)$ made explicit in (18) below, but might plausibly apply in circumstances more general than those of the present model.[26] At low levels of the minimum, the positive effects in (14) dominate: this can be seen by noting that evaluating the impact at $\mu = t^N$, gives, using the envelope property, $w'(t^N) = w_T(t^N, T(t^N))T'(t^N)$, with both W_T and T' seen above to be strictly positive. Welfare in the low tax country continues to rise with the minimum for some while, but the revenue loss from the decline in profit shifting looms increasingly large. Eventually the point is reached at which a further slight increase in the minimum rate produces a contraction in the profit-shifting-inclusive

[26] Also shown is welfare in the high tax country, strictly increasing and (readily seen to be) convex, at all levels of μ above t^N.

tax base of the low rate country that exactly offsets the additional gain from charging that (now narrower) base, and the domestic base, at a higher rate. Welfare $w(\mu)$ thus reaches a peak at some minimum rate μ^*: this is the *Pareto efficient minimum tax rate*, in the sense that any other minimum rate leads to lower welfare in the low tax country. As μ increases beyond this point, the reduction in the low tax country's shifting-inclusive tax base dominates the impact of taxing it at a higher rate, and welfare in the low tax country begins to fall. And at some minimum rate μ^{**} it falls to such a level that $\omega(\mu^{**}) = w^N$, so that welfare in the low tax country is as it was in the Nash equilibrium; at higher minima, it is strictly less. We refer to μ^{**} as the *maximal Pareto dominant minimum rate*, being the highest level at which the minimum can be set without making the low tax country worse off than in the Nash equilibrium.

Figure 2 shows these effects in terms of the familiar diagrammatic structure of the underlying game. By introducing flat segments in both best responses at rates below that level, the effect is to shift the Nash equilibrium from A to B. The low tax country, sure to gain from a minimum sufficiently close to the rate it sets in the uncoordinated Nash equilibrium (because its iso-welfare contours are horizontal where they meet its best response), continues to gain relative to the Nash equilibrium at any minimum below that at point C, where the iso-welfare contour through A intersects the best response of the high tax country: this is the level μ^{**}. Its most preferred minimum, μ^*, is at D, where an iso-welfare contour is tangential to the high tax country's best response.[27]

Before characterizing μ^* and μ^{**}, recognition is needed of the complication mentioned above: since the rate set by the low tax country increases less than one-for-one with the minimum rate, at some level, given (from 8), by

$$\bar{\mu} \equiv \left(\frac{\Lambda - 1}{\Lambda}\right)\delta, \tag{15}$$

the minimum will come to bind on the high tax country too. This corresponds to the point E in Figure 2, at which $T(t)$ cuts the 45° line. At minima higher than $\bar{\mu}$, both countries set their rate at the minimum, and it is then readily verified that (with both λ and Λ fixed and strictly greater than unity) welfare in each country rises indefinitely with further increases in μ. This is, however, a relatively uninteresting possibility, both because at some point the assumption that marginal valuations of public spending do not decline with revenue would become untenable and, still more fundamentally, because setting such a minimum is equivalent to complete harmonization, and at

[27] This illustrates the remark in Section 2 that μ^* is the rate that the low tax country would set if it were first mover, so that minimum taxation cannot then be strictly Pareto-improving.

a rate that is strictly above the higher of the Nash equilibrium rates[28]—none of which is on any political agenda, For brevity, attention in what follows is therefore restricted to $\mu \leq \bar{\mu}$.

With this, the critical values of the minimum rate are readily seen to be given by:

Proposition 2. *(a) The Pareto efficient minimum tax rate is given by* $\max(\mu^*, \bar{\mu})$, *where*

$$\mu^* = \delta\left(\frac{(\lambda-1)(\Lambda-\alpha)2\theta + \lambda(\Lambda-1)}{2\lambda\Lambda}\right). \tag{16}$$

(b) The maximal Pareto dominant minimum rate is given by $\max(\mu^{**}, \bar{\mu})$, *where*

$$\mu^{**} = \delta\left[\frac{(\Lambda-\alpha)^2}{\Lambda(3\lambda-2\alpha)}\right]\left[\left(\frac{\lambda-1}{\lambda}\right)4\theta + \left(\frac{2(\Lambda-1)}{\Lambda-\alpha}\right)\right] > \mu^*. \tag{17}$$

Proof. For part (a), since $W(\mu)$ is everywhere increasing, the Pareto efficient minimum is that which maximizes $w(\mu)$. For this, it is readily seen (recalling that $T' < 1$ and $T'' = 0$) that $w(\mu)$ is strictly concave, so that a unique maximum is found by setting $w'(\mu^*) = 0$ in (14); substituting from (8) for both $T(\mu) - \mu$ and $T' - 1$, and rearranging to arrive at (16).

For part (b), using (8) to substitute for $T(\mu)$ in (13) and collecting terms gives

$$w(\mu) = \delta\theta + \delta\left(\frac{\lambda(\Lambda-1)}{2(\Lambda-\alpha)} + (\lambda-1)\theta\right)\mu - \left(\frac{\lambda\Lambda}{2(\Lambda-\alpha)}\right)\mu^2. \tag{18}$$

The symmetry of this quadratic structure implies (as may be visualized from Figure 1)[29] that $\mu^{**} = t^N + 2(\mu^{**} - t^N) = 2\mu^* - t^N$; the expression for μ^{**} in (17) then follows from (10) and (16). □

The comparative statics of the Pareto efficient and maximal Pareto dominant rate in Proposition (2) are again mostly straightforward. But for present purposes they are in an important sense beside the point, since what is of interest are not the levels of μ^* and μ^{**} as such, but how they compare, in particular, with the initial low tax rate t^N.

[28] To see this diagrammatically: with $T^N > t^N$, the upward-sloping best response of the high tax country in (t, T) space must cut the 45° line at a rate higher than T^N.

[29] For a direct proof, write (18) as $w(\mu) = A\mu^2 + B\mu + C$, so that the necessary condition defining μ^* is $2A\mu^* + B = 0$, and define $x \equiv \mu^* - t^N$. Then $w(\mu^{**}) = w(t^N)$ implies that

$$\begin{aligned} w(\mu^{**}) = w(\mu^* - x) =& A(\mu^{*2} + x^2 + 2\mu^* x) + B(\mu^* - x) - 4A\mu^* x + C \\ =& A(\mu^* + x)^2 + B(\mu^* - x) + 2Bx + C \\ =& A(\mu^* + x)^2 + B(\mu^* + x) + C \\ =& w(\mu^* + x). \end{aligned}$$

Hence, $\mu^{**} = t\mu^* + x = 2\mu^* - t^N$.

Before turning to this, however, it remains to characterize the levels of the Pareto efficient and maximally dominant rates relative to that at which the high tax country also becomes constrained, since it is this that shapes the commonality or conflict of interest in setting the minimum rate. Bearing in mind that $\mu^* < \mu^{**}$, three possibilities arise:

- *Unanimity* (Case U): $\bar{\mu} \leq \mu^*$, so that a higher minimum always benefits both countries. Comparing (15) and (16), this will be the case iff

$$\frac{(\Lambda - 1)/\Lambda}{(\lambda - 1)/\lambda} < \left(\frac{\Lambda - \alpha}{\Lambda}\right) 2\theta. \tag{19}$$

- *Potential conflict* (PC): $\mu^* \leq \bar{\mu} < \mu^{**}$, meaning that although the low tax country always gains relative to the Nash equilibrium, there is potential conflict in that beyond some point, but before the high tax country becomes constrained, the low tax country loses from marginal increases in the minimum rate. This arises when neither (19) nor (20) below applies.

- *Potential loss* (PL): $\mu^{**} < \bar{\mu}$, so that there exist minima that do not bind the high tax country but nevertheless imply a loss of welfare for the low tax country relative to the uncoordinated Nash equilibrium. Comparing (17) with (15), this case—which is that illustrated in Figure 2 above—arises iff

$$\frac{(\Lambda - 1)/\Lambda}{(\lambda - 1)/\lambda} > \left(\frac{\Lambda - \alpha}{\Lambda}\right)^2 4\theta. \tag{20}$$

These three possibilities are illustrated in Figure 1: Cases PL, PC and U arise if $\bar{\mu}$ is at the illustrative levels $\bar{\mu}^{PL}$, $\bar{\mu}^{PC}$ and $\bar{\mu}^{U}$, respectively.

Equations (19) and (20) confirm, unsurprisingly, that the scope for conflict—moving through cases U to PC to PL—is greater the more marked are dissimilarities in size or valuation of revenue. Suppose, for instance that $\alpha = 0$ and that the two countries differ only in size: then there is unanimity if $\theta > 0.5$ and potential loss for the low tax country if (far from implausible) $\theta < 0.25$. If they differ only in the valuation of revenue, then a similar partition applies in terms of the ratio of $(\lambda - 1)/\lambda$ to $(\Lambda - 1)/\Lambda$.[30]

3.2 Further Issues

The assumption so far has been that the low tax country has no alternative to setting the prescribed minimum rate. Suppose, however, that is has the option of defecting, setting a rate below μ, and

[30]So, for instance, if $\lambda = 1.2$ then Case U arises unless $\Lambda > 1.5$.

that the timing is such that the high tax country continues to set $T(\mu)$ while the multinational in the high tax country is able to take advantage of this lower rate. In a repeated game context, the attractions of doing so will depend on what happens in periods after that defection. The simple and natural assumption here is that the outcome reverts in perpetuity to the Nash equilibrium of the previous sentence; and since that is independent of the minimum rate, the level of that minimum affects the incentive to defect only through its impact on the one-period gain it generates. It is then straightforward to show that the gain to the low tax country from defecting increases with the minimum rate (see Appendix A). At a sufficiently high minimum (depending also on the discount rate applied to future payoffs), the low tax country will thus wish to defect from the agreement. The significance of this potential instability in the context of the recent G-20/OECD agreement is not entirely clear, however, since (in the language of the current model) the high tax country retains the ability to top-up liability to the minimum;[31] in which case, as noted earlier, the low tax country has an incentive to raise its own tax to the minimum. In this wider sense, the G-20/OECD agreement is arguably self-enforcing.

Though not a focus here, the question also arises as to how joint welfare, $w + W$, varies with the minimum rate. Clearly it is strictly increasing at least to some level higher than the preferred minimum rate μ^*. Indeed it is sufficient (but not necessary) for joint welfare to be everywhere increasing in μ that $\Lambda > \lambda$:[32] intuitively, the loss to the low tax country from the reduction in profit shifting that eventually sets in at higher levels of μ is then always less than the corresponding gain to the high tax country. In other cases the possibility arises of an interior maximum, but few further insights seem to come from its characterization.

3.3 Calibration

A strikingly sharp answer to the questions of where the Pareto efficient and maximally dominant rates stand relative to the rate initially set by the low tax country emerges on comparing (16) and (17) with (10) to immediately find:

[31] In practice, it is not clear why any agreement should be necessary to achieve this, since high tax countries already have the capacity to do this through their domestic legislation. But this is a broader mystery with the politics of the agreement, which we do not enter into here.

[32] Denoting the maximized welfare of the high tax country by $W(\mu) \equiv W(T(\mu), \mu)$, differentiating in (6) and using the envelope theorem gives $W'(\mu)\delta/\Pi = W_t(T(\mu), \mu)\delta/\Pi = (\Lambda - 2\alpha)T(\mu) + 2\alpha\mu > 0$. Adding the latter equation and (14) gives

$$(w'(\mu) + W'(\mu))\delta/\Pi = (\lambda - 1)\delta\theta + \lambda\mu T' + (\Lambda - 2\alpha)(T(\mu) - \mu) + (\Lambda T - \lambda\mu).$$

Each of the first three terms on the right is strictly positive; with $T(\mu) > \mu$, so too is the fourth if $\Lambda > \lambda$. And if the constraint bites on the high tax country, we have already noted that welfare in both countries is strictly increasing in μ.

Proposition 3. *The Pareto efficient and maximally dominant minimum rates are related to the lowest tax rate of the uncoordinated Nash equilibrium as:*

$$\mu^* = \left(\frac{3\Lambda - 2\alpha}{2\Lambda}\right)t^N \tag{21}$$

$$\mu^{**} = \left(\frac{2(\Lambda - \alpha)}{\Lambda}\right)t^N. \tag{22}$$

The gaps between these two rates and t^N, and between μ^* and μ^{**} themselves, thus depend upon only, and are strictly decreasing in, the ratio α/Λ. The reason, as can be seen from Figure 2, is that the low tax country is more likely to gain from the imposition of a minimum rate the steeper is the best response of the high tax country, since that implies a greater increase in the high tax rate—and the slope of that best response, as discussed above, is decreasing in α and increasing in Λ. Indeed it depends only on the ratio α/Λ: the best response of the high tax country is steeper the lower is the valuation there of the private gains from outward profit shifting relative to that of the tax revenue it dissipates.

Taking for illustration a benchmark low tax rate of $t^N = 12.5\%$ (the rate in Ireland, recall, which has occupied such a central place in the policy debate), Figure 3 illustrates the relationships in (21) and (22), showing also the ranges in which the three cases above arise and the slope of the best response $T'(t)$. With α/Λ at its highest possible value of 0.5—attained when both the private gain from profit shifting and tax revenue are valued by the high tax country like private income (so that $\alpha = 0.5$ and $\Lambda = 1$)—there is no possibility of any Pareto gain from imposing a minimum tax: the best response of the high tax country is perfectly flat. At the opposite extreme, when the high tax country cares only about tax revenue or attaches no value to the private gain from profit shifting ($\Lambda \to \infty$ or $\alpha = 0$, with $T'(t)$ reaching its maximum of $1/2$), both μ^* and μ^{**} reach upper bounds. And these are both very substantially above the initial low rate of 12.5%: the Pareto efficient rate is 18.75%, and both countries gain from any minimum rate not exceeding 25%.

Outcomes are of course less extreme at intermediate values of α/Λ, but still suggest material scope for mutual gain. Suppose for instance that $\Lambda = 1.5$. If the private gains from profit shifting are fully valued ($\alpha = 0.5$), so that $\alpha/\Lambda = 1/3$, then $\mu^* = 14.6$ while $\mu^{**} = 16.7\%$. While these numbers may seem close to the low rate of 12.5%, in the context of the current policy debate the differences are material: it is a striking implication, for instance, that a country initially setting a rate of 12.5% might ultimately benefit from being subjected to a minimum of close to 17%. And the apparent scope for mutual gain becomes still wider at lower values of α/Λ, which imply (higher) values for the slope $T'(t)$ that are still within the range suggested by the empirical literature. Suppose, for instance, again taking $\Lambda = 1.5$, that profit shifting gains are valued at only half of other private income (so that $\alpha/\Lambda = 1/6$ and $T'(t) = 0.4$): then the low tax country's preferred minimum rate is then 16.7%, and it benefits from any minimum up to 20.8%.

The impression of significant prospect of Pareto improvement from the imposition of a minimum tax emerges from the calculations for a wider range of parameter values reported in Table 1. Again taking $t^N = 12.5\%$, this reports, along with implied values of μ^* and μ^{**}, the corresponding values of the high Nash rate, T^N, the level of the minimum at which the high tax country becomes constrained, $\bar{\mu}$, and which of the three possible configurations of interests applies. (Unlike μ^* and μ^{**}, all of these depend on more than simply the ratio α/Λ). The scope for some dissonance of interests, indicated by the last column, is evident. For example, whenever the high tax rate is 20% or more—a plausible counterpart to calibrating the low rate at 12.5%—Case PL arises, meaning that the low tax country may lose, relative to the Nash equilibrium, from some minimum rates that are ambitious but leave the high tax country unconstrained. Still more notable, however, is that it is only at levels in the order of 17-24% that the adoption of a minimum rate leaves the low tax country worse off than in the initial Nash equilibrium.[33]

3.4 A Three Country Extension

The two country case enables a tractable and analytically rich exploration of interactions and contrasts between high and low tax countries that is at the heart of international tax competition. But the world is of course more complex, and further nuances in the impact of a minimum tax arise in a many-country world. To give come sense of these, Appendix B extends the model above to a three-country world. This comprises a low tax country, essentially as above, but now with both a high- and an intermediate- tax country, dissimilar but structurally also much as above, and each shifting profits to the low tax jurisdiction,[34] but differing in the value Λ_i attached to tax revenue and potentially also in the scale of profits Π_i. It is shown there that, as above, the preferred and Pareto dominant rates for the low tax country can be conveniently expressed as simple (though now less simple) multiples of the rate that the lowest tax country sets in the unconstrained Nash

[33] Also worth noting is that, in contrast to the Kanbur and Keen (1993) result noted earlier, there are examples in which $\mu^{**} < T^N$, so that the maximally dominant rate is below the higher of the tax rates in the uncoordinated Nash equilibrium. That earlier result is recaptured here by using (8), (10) and (22) to show that $\lim_{\lambda,\Lambda\to\infty}[(\mu^{**} - T^N)/\delta] = \theta > 0$.

[34] Costs of profit shifting are assumed to depend only on the total amount shifted, so that shifting from the highest tax country is only to the lowest, not to the intermediate country.

equilibrium.

The principal difference relative to the two country case is an intuitively straightforward 'ripple' effect that tends to expand the scope for the lowest tax country to gain from a binding minimum. As the minimum constraining the low tax country is increased, so the intermediate country tends to raise its tax rate, which in turn induces an increase of that in the highest tax country. Intuitively, these effects amplify the potential net gain to the low tax country, with the result that both preferred and maximally dominant rates, μ^* and μ^{**}, are higher than would otherwise be the case. It is hard to make this point precise, since introducing a third country into a two country game will generally lead to different outcomes for the initial two. But suppose, for instance, that for the low tax country $\lambda = 1.7$ while for the others $\Lambda_1 = 1.2, \Lambda_2 = 1.1$, that profits in countries 1 and 2 are each twice as large as in the low tax country, and that $\alpha = 0.3$. Presuming the lowest tax rate again to be 12.5%, the results in Appendix B imply that the highest tax rate in the uncoordinated equilibrium is then $T_1^N = 26.3\%$. The lowest and highest rates are thus much as in Table 1, with the latter 3 or 4 points higher than there. Now though there is also an intermediate country, which sets a rate of $T_2^N = 17.9\%$. And the Pareto efficient rate is no longer $15 - 18\%$ but 23.9%; that is, has increased by 6-8 points (far more than has the highest Nash rate itself). And the maximally dominant rate rises by even more, to 35.3%.

4 Conclusions

The purpose of adopting a minimum rate of corporate taxation is to change the rules of the game of international tax competition, especially in relation to profit shifting. How countries respond to those changed rules—including those countries that are not directly affected—must thus be a central part of assessing the effects and desirability of such a minimum, and hence in providing some guidance both as to the level at which such a minimum might be set and to the potential convergence and conflicts of interest that arise in this choice.

In general, these strategic responses mean that a low tax country may either benefit from or be harmed by a minimum tax at just above the rate they set in the initial equilibrium. Empirical results which strongly suggest statutory tax rates to be strategic complements, and the likelihood in a context of profit shifting that each country benefits from a tax increase by the other, point to the most plausible outcome being a welfare gain for the low tax country. The presumption that the high tax country gains from a minimum rate being strong, the implication is that an infinitesimally binding minimum rate is Pareto-improving.

But that simply directs attention to the two key questions raised at the outset, both critical for policy: how high are the Pareto efficient and maximal Pareto dominant minimum rates? While no model can provide definitive answers, analysis can give a sense of their key drivers and the range of possibilities. In that spirit, what emerges here as critical is not merely the sign but also the magnitude of the slope of the best response in the high tax country. In the model here, this turns on the valuation in the high tax country of the private gain from profit shifting relative to the public loss. Importantly, however, from the perspective of the low tax country it is immaterial what drives that slope: all that matters is the magnitude that results. Empirical work does not give great confidence in speculating on this. Nonetheless, the simulations reported here suggest that for plausible parameter values both Pareto efficient and maximal dominant rates may indeed lie materially above the initial low tax rate. It is not difficult, for instance, to provide reasonable parameter values which suggest, given an initial low rate of 12.5%, that both high and low tax countries gain from a minimum as high as 17-20%. These may seem small differences. But in the context of a debate in which candidate rates have been within the range 12.5-20%, and disagreement heated, they are quite salient. The implication is thus that national interests may align around minima that are materially above the lowest urged by some.

Some extensions of the central model analyzed here, we have seen, leave this key message intact. Extending to more than two countries, for instance, the strategic response to a minimum binding on the lowest tax country involves an additional ripple-like effect (increasing all rates from the lowest upwards) that seems likely to lead to a still higher levels of the Pareto efficient and maximally dominant minimum rates. And adopting a perspective of collective efficiency makes the likelihood of gain even larger. That said, there are evidently more considerations raised by minimum corporate taxation than can be addressed here. Prominent among these is the impact on real investment, the analysis of which requires a richer framework, in which both tax rate and base matter. Nonetheless, the core point remains. Even without side payments, in its impact on profit shifting—which is the primary motivation underlying the recent agreement—the scope for a congruence of interest in setting an ambitious minimum rate may be larger than is commonly recognized.

Appendix A: The gain from defecting is strictly increasing in μ

Denote the one-period welfare gain to the low tax country from defecting by $D(\mu) \equiv w^D(\mu) - w(\mu)$, where $w^D(\mu) = w(t[T(\mu)], T(\mu))$ is the low tax country's maximized welfare given defection (obtained by setting its best response to $T(\mu)$) and $w(\mu)$, as in (13), is its welfare when abiding by the minimum. Recalling (1),

$$w^D(\mu)\delta/\Pi = \delta(1 - t[T(\mu)])\theta + \lambda t[T(\mu)]\big(\delta\theta + T(\mu) - t[T(\mu)]\big) \tag{A.1}$$

which, since, from (3),

$$T(\mu) - t[T(\mu)] = \frac{1}{2}\left[T(\mu) - \left(\frac{\lambda - 1}{\lambda}\right)\delta\theta\right], \tag{A.2}$$

reduces to

$$w^D(\mu)\delta/\Pi = \kappa + \frac{1}{2}\delta\theta T(\mu) + \frac{1}{4}\lambda T(\mu)^2 \tag{A.3}$$

where $\kappa \equiv \delta\theta + \frac{(\lambda-1)^2\delta^2\theta^2}{4\lambda}$. Evidently $D(\mu) > 0$ for all $\mu > t^N$, since defection is to the low tax country's best response to $T(\mu)$ (which is readily verified to be below μ). Differentiating twice in (A.3) and using the implication of (8) that $T''(\mu) = 0$ shows that $w^D(\mu)$ is strictly convex. Since, as seen in the text, $w(\mu)$ is strictly concave, it follows that $D(\mu)$ is strictly convex. With $D(\mu) > 0$ and $D(t^N) = 0$, it must be that $D'(\mu) > 0$ for μ arbitrarily close to μ. It follows that $D\prime(\mu) > 0$ for all $\mu > t^N$.

Appendix B: Extension to three countries

We label countries so that, under conditions established below, the tax rates they charge in the Nash equilibrium are such that $T_1^N > T_2^N > t$ (retaining the lower case notation for the lowest tax country 3). Countries 1 and 2 have the same characteristics as the high tax country of the main text, differing in that $\Lambda_1 > \Lambda_2$ and possibly also in the scale of their profits Π_i. The cost of outward profit shifting is assumed to depend only on the amount shifted, not on where it is shifted to; all profit shifting will thus be to country 3. We assume too that $\theta \equiv \pi/(\Pi_1 + \Pi_2) < 1$.

Welfare in country 3, reflecting inward profit shifting from the other two countries, is then

$$w = (1-t)\pi + \lambda t\left(\pi + \left(\frac{T_1 - t}{\delta}\right)\Pi_1\right) + \left(\frac{T_2 - t}{\delta}\right)\Pi_2\Bigg) \tag{B.1}$$

so that

$$w\delta/(\Pi_1 + \Pi_2) = (1 + (\lambda - 1)t)\delta\theta + \lambda t(\tau - t) \tag{B.2}$$

where

$$\tau \equiv T_1\Theta_1 + T_2\Theta_2. \tag{B.3}$$

in which $\Theta_i \equiv \Pi_i/(\Pi_1 + \Pi_2)$ for $i = 1, 2$. Maximizing with respect to t gives the lowest tax country's best response as

$$t(\tau) = \frac{1}{2}\left[\left(\frac{\lambda - 1}{\lambda}\right)\delta\theta + \tau\right]. \tag{B.4}$$

Since countries 1 and 2 each interact only with the lowest tax country 3, by analogy with (8) their best responses are given by

$$T_i(t) = a_i + b_i t \tag{B.5}$$

where

$$a_i \equiv \frac{1}{2}\left(\frac{\Lambda_i - 1}{\Lambda_i - \alpha}\right)\delta; \quad b_i = \frac{1}{2}\left(\frac{\Lambda_i - 2\alpha}{\Lambda_i - \alpha}\right), \quad i = 1, 2. \tag{B.6}$$

Defining $a \equiv a_1\Theta_1 + a_2\Theta_2$ and $b \equiv b_1\Theta_1 + b_2\Theta_2$, using (B.5) in (B.3) gives

$$\tau(t) = a + bt, \tag{B.7}$$

and hence, from (B.4), the Nash rate in the lowest tax country is given by

$$t^N = \frac{\left(\frac{\lambda-1}{\lambda}\right)\delta\theta + a}{2 - b}. \tag{B.8}$$

To establish the most preferred minimum tax of the lowest tax country, μ^*, set $t = \mu$ and (recalling (B.7)) $\tau = a + b\mu$ in (B.2) to write welfare there as

$$w\delta/(\Pi_1 + \pi_2) = (1 + (\lambda - 1)\mu)\theta + \lambda\mu(a + (b - 1)\mu). \tag{B.9}$$

Maximizing with respect to μ and rearranging the necessary condition[35] $(\lambda - 1)\delta\theta + \lambda(a + 2(b - 1)\mu^*) = 0$ gives

$$\mu^* = \frac{1}{2}\left[\frac{\left(\frac{\lambda-1}{\lambda}\right)\delta\theta + a}{1 - b}\right], \tag{B.10}$$

comparing which with t^N in (B.8) gives

$$\mu^* = t^N\left(\frac{2 - b}{2(1 - b)}\right). \tag{B.11}$$

For the maximal Pareto dominant rate μ^{**}, since welfare in (B.9) is quadratic in μ, the same logic as in the text implies that $\mu^{**} = t^N + 2(\mu^* - t^N) = 2\mu^* - t^N$; hence, from (B.11),

$$\mu^{**} = t^N\left(\frac{1}{1 - b}\right). \tag{B.12}$$

It remains to establish conditions for the existence, for high enough Λ_i, of the equilibrium just presumed. First, since the best responses in (B.5) are increasing in Λ_i, the assumption that $\Lambda_1 > \Lambda_2$ implies that $T_1^N > T_2^N$. Second, that $T_2^N > t$ requires, again from (B.5), that $a_2 + (b_2 - 1)t^N > 0$; from (B.8), this is equivalent to[36]

$$\frac{(2 - b)a_2}{1 - b_2} - a > \left(\frac{\lambda - 1}{\lambda}\right)\delta\theta. \tag{B.13}$$

That both conditions can be satisfied, for large enough Λ_2, can be seen by taking $\Lambda_1 = \Lambda_2 + \epsilon$, with $\epsilon > 0$ and letting $\Lambda_2 \to \infty$. The latter gives $a_2 \to (1/2)\delta$ and $b \to (1/2)$, so that the left of (B.13) converges to $(3/2)\delta$; since $\theta < 1$, (B.13) is then also satisfied.

[35] That the second order condition, $(b - 1) < 0$, is satisfied follows on recalling the definition of b after (B.6), in which each $\Theta_i > 0$, and, from the latter part of (B.6), that $b_i - 1 = -\lambda_i/(\Lambda_i - \alpha)$.

[36] The rearrangement here uses $b_2 < b < 1$.

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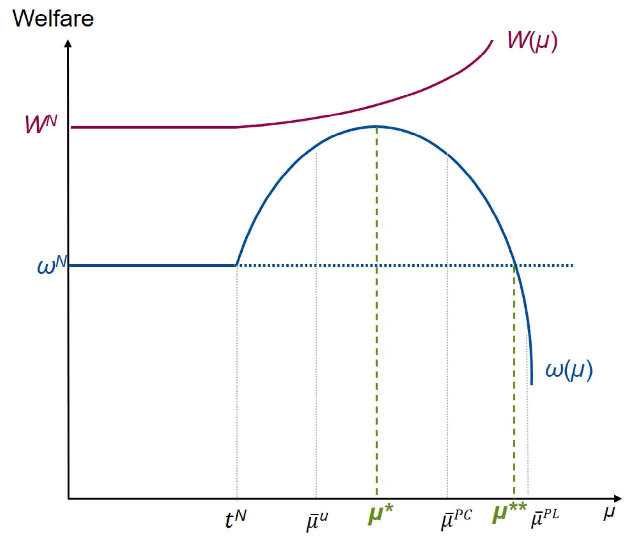
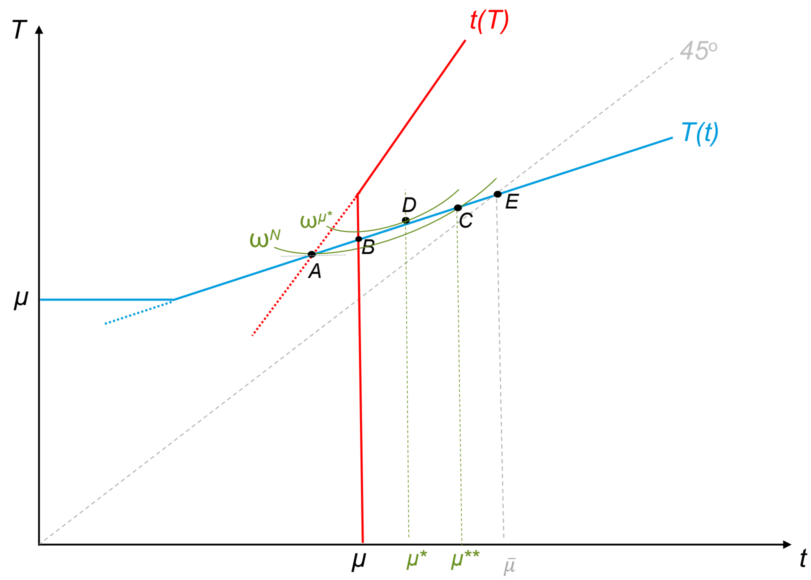
Figure 1: *The Welfare Impact of Minimum Taxation*



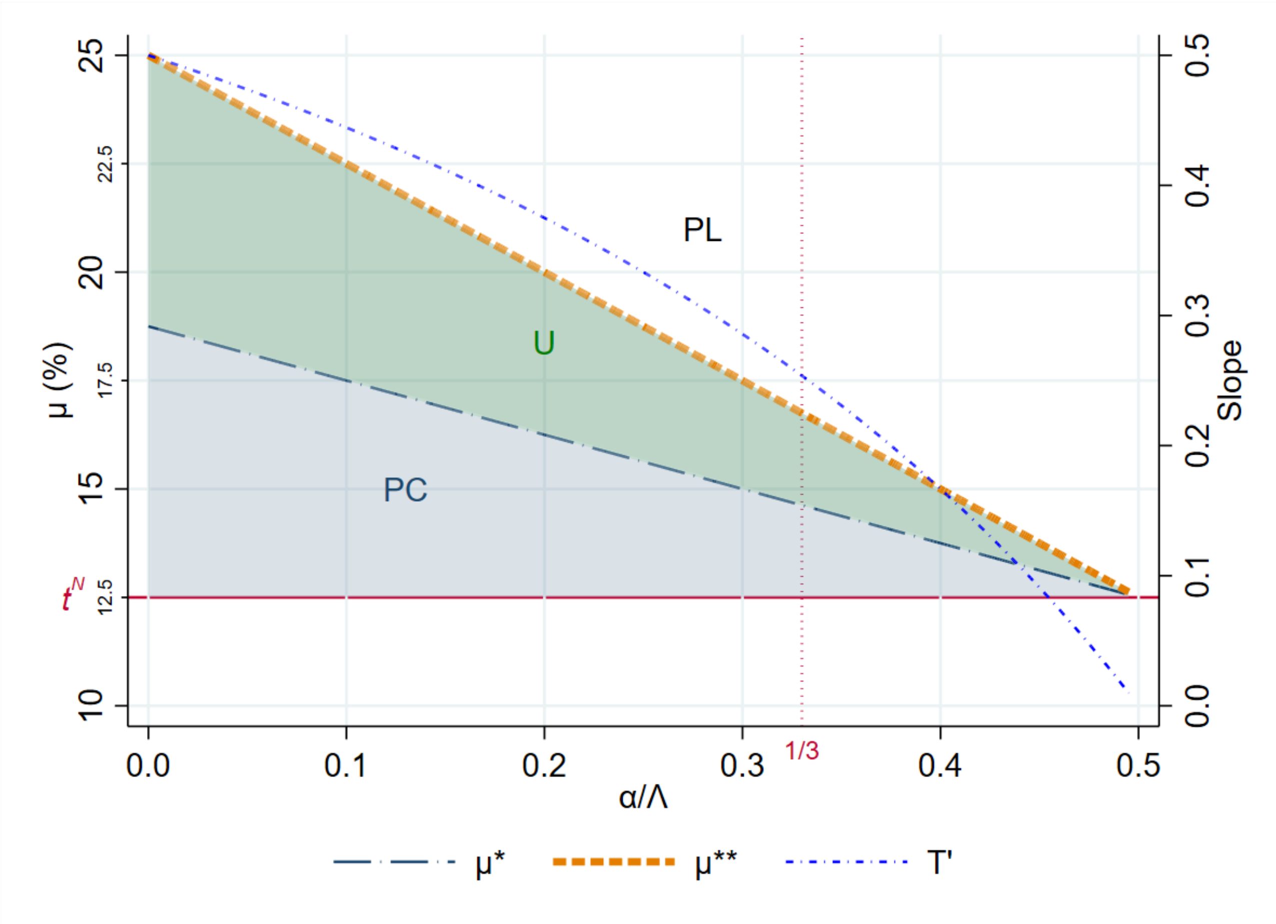
Note: The figure shows how welfare in each of the two countries varies with the level of the minimum tax rate μ, relative to their levels in the uncoordinated (Nash) equilibrium, w^N and W^N. The minimum has effect only once it exceeds the lower of the tax rates in the uncoordinated equilibrium, t^N. Welfare of the high tax country $W(\mu)$ increases throughout, because the enforced increase in the tax rate of the low tax country reduces its vulnerability to revenue loss from outward profit shifting. Welfare in the low tax country, $w(\mu)$, initially increases, as the increased revenue from both domestic taxpayers and the profit shifting that remains outweighs the revenue loss from reduced profit shifting. The latter effect (which arises because the high tax country reduces its rate less than one-for-one with the minimum) looms increasingly large, however, in the impact on the low tax country. Welfare in the low tax country thus reaches a peak, at the Pareto efficient level μ^*. It then declines, eventually falling below its level in the uncoordinated equilibrium, w^N at the maximally Pareto dominant rate μ^{**}. Points $\bar{\mu}^U$, $\bar{\mu}^{PC}$ and $\bar{\mu}^{PL}$ represent alternative hypothetical levels at which the minimum binds the high tax country, as discussed below. There is no significance to the relative levels of $w(\mu)$ and $W(\mu)$.

Figure 2: *Implications of a Minimum Tax Rate*



Note: This figure shows how a minimum tax reshapes the underlying game and equilibrium. In the absence of the minimum, the Nash equilibrium is at point A, where the unconstrained best responses of the two countries, $t(T)$ and $T(t)$ intersect. A minimum rate of μ enforces a vertical segment into the low tax country's best response, shifting the equilibrium to B. The minimum rate most preferred by the low tax country is at D, where one of its iso-welfare contours is tangential to $T(t)$: this is the Pareto efficient rate μ^*. The highest rate at which the low tax country gains relative to the uncoordinated equilibrium is at C, where the iso-welfare contour through A intersects the best response of the high tax country: this is the maximally Pareto dominant rate, μ^{**}. Once the minimum exceeds $\bar{\mu}$, the unconstrained best response of the high tax country, at point E, lies below the minimum; so that minimum binds the high tax country too.

Figure 3: *Efficient Minimum Tax Rates*



Note: This figure shows, conditional on an uncoordinated low tax rate of $t^N = 12.5\%$: On the left hand scale, the Pareto efficient and maximally Pareto dominant minimum tax rates μ^* and μ^{**}, from (21) and (22); on the right hand scale, the slope $T'(t)$ of the high tax country's best response, calculated from (8). The shaded regions correspond to the three cases described at the end of section 3.1.
For example: Suppose $\alpha/\Lambda = 1/3$, so that the social valuation that the high tax country places on the private gain from profit shifting is one-third of that it places on tax revenue. And suppose too that the minimum tax is set at 15%. Then case *PC* applies, meaning that the low tax country would prefer a minimum lower than 15%, but is nonetheless better off than in the uncoordinated equilibrium. By way of information, the slope of the best response of the high tax country in these circumstances is 0.25.

Table 1: *Efficient and Dominant Minimum Tax Rates for Different Parameterizations*

	Panel (a) *α =0.5*						
	θ (size)	T^N	$T'(t)$	***μ****	***μ*****	$\bar{\mu}$	
		Nash rate (high-tax country)	*Slope of T(t)*	Pareto efficient minimum rate	Maximal Pareto dominant minimum rate	*Binding minimum rate*	**CASE**
λ=1.2; Λ=1.7	1	17.23	0.29	15.07	17.65	19.18	PL
	0.75	18.59	0.29	15.07	17.65	21.10	PL
	0.5	20.25	0.29	15.07	17.65	23.45	PL
	0.25	22.33	0.29	15.07	17.65	26.38	PL
	0.1	23.85	0.29	15.07	17.65	28.52	PL
Λ = λ = 1.5	1	12.50	0.25	14.58	16.67	12.50	U
	0.75	14.06	0.25	14.58	16.67	14.58	PC
	0.5	16.25	0.25	14.58	16.67	17.50	PL
	0.25	19.53	0.25	14.58	16.67	21.88	PL
	0.1	22.43	0.25	14.58	16.67	25.74	PL
	Panel (b) *α =0.3*						
	θ (size)	T^N	$T'(t)$	***μ****	***μ*****	$\bar{\mu}$	**CASE**
λ=1.2; Λ=1.7	1	16.96	0.39	16.54	20.58	19.85	PC
	0.75	18.30	0.39	16.54	20.58	22.06	PL
	0.5	19.98	0.39	16.54	20.58	24.82	PL
	0.25	22.13	0.39	16.54	20.58	28.36	PL
	0.1	23.74	0.39	16.54	20.58	31.02	PL
Λ = λ = 1.5	1	12.50	0.37	16.25	20	12.50	U
	0.75	13.92	0.37	16.25	20	14.87	U
	0.5	16.07	0.37	16.25	20	18.16	PC
	0.25	19.20	0.37	16.25	20	23.21	PL
	0.1	22.20	0.37	16.25	20	28.02	PL
	Panel (c) *α =0.1*						
	θ	T^N	$T'(t)$	***μ****	***μ*****	$\bar{\mu}$	**CASE**
λ=1.2; Λ=1.7	1	16.72	0.47	18.01	23.53	20.45	PC
	0.75	18.04	0.47	18.01	23.53	22.93	PC
	0.5	19.72	0.47	18.01	23.53	26.09	PL
	0.25	21.94	0.47	18.01	23.53	30.26	PL
	0.1	23.64	0.47	18.01	23.53	33.48	PL
Λ = λ = 1.5	1	12.50	0.46	17.92	23.33	12.50	U
	0.75	13.80	0.46	17.92	23.33	14.93	U
	0.5	15.73	0.46	17.92	23.33	18.53	PC
	0.25	18.89	0.46	17.92	23.33	24.43	PL
	0.1	21.98	0.46	17.92	23.33	30.20	PL

Note: The low tax rate in the uncoordinated equilibrium, t^N, is in all cases 12.5%, with the values for μ^* and μ^{**} then given by (21) and (22). By eliminating δ, both T^N (combining (10) and (11)) and $\bar{\mu}$ (combining (10) and (15)) can be expressed as multiples of t^N that depend only on the parameters varied in the table.