How Do Corporate Tax Bases Change When Corporate Tax Rates Change? With Implications for the Tax Rate Elasticity of Corporate Tax Revenues[*]

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Abstract

We construct a new database of extensive margin changes to multiple aspects of corporate tax bases for OECD countries between 1980 and 2004. We use our data to systematically document the tendency of countries to implement policies that both lower the corporate tax rate and broaden the corporate tax base. This correlation informs our interpretation of previous estimates of the relationship between corporate tax rates and corporate tax revenues, which typically do not include comprehensive measures of the corporate tax base definition. We then re-examine the relationship between corporate tax rates and corporate tax revenues. We find that accounting for unobserved heterogeneity attenuates the relationship between corporate tax rates and corporate tax revenues, and increases the implied revenue-maximizing tax rate. Controlling for our new tax base measures does not substantively impact the magnitude of this relationship.

Keywords: Corporate taxation; Corporate tax revenues
JEL codes: H25

1   Introduction and motivation

The large literature on the effect of tax systems on corporate behavior has focused on the impact either of the statutory corporate tax rate or of an effective tax rate that depends on the statutory rate and depreciation schedules. In reality, though, the corporate tax system has myriad dimensions, and ignoring the effects of these other dimensions can bias the estimated effect of the corporate tax rate and narrow one's impression of the potential impact of the full set of tax instruments. The former is especially likely if the non-rate dimensions of the corporate tax system change concurrently with the headline statutory rate. This issue is widely recognized, but its quantitative importance is unknown due to the paucity of comprehensive information about changes in the non-rate aspects of corporate tax systems.

In this paper we remedy this situation by compiling a new, comprehensive dataset of the occurrences of changes in multiple aspects of corporate tax bases for OECD countries from 1980 and 2004. These data are based on summaries of important tax policy changes from the International Bureau of Fiscal Documentation's Annual Reports publications, from which we construct measures of extensive margin changes to 12 different aspects of the corporate tax base. Using this new dataset, we first characterize the systematic relationship between statutory rate changes and changes to several categories of the tax base as well as the enforcement regime. This relationship is relevant for the interpretation of empirical studies on the consequences of corporate tax rate changes, which generally omit these other dimensions of the corporate tax system, which we will refer to as base changes. Because of this omission, the correlation between rate changes and base changes (together with hypotheses about the independent effect of base changes) is informative about the direction of bias in estimates that are obtained when econometric models exclude such variables. Although this issue has not heretofore been addressed systematically, it is well known that base changes have been prominent in recent tax reforms, at least since the landmark U.S. Tax Reform Act of 1986, which dramatically lowered corporate tax rates but was expected to increase revenue due

to the elimination of the investment tax credit, the scaling back of accelerated depreciation allowances and other tax base broadeners.

We document that corporate tax base changes in OECD countries are more likely to occur in years when there is a change to the corporate tax rate, raising concerns about the appropriateness of ignoring base changes in a study of the consequences of rate changes. In 53% of country-years with corporate tax rate changes, there is also a change to the corporate tax base. In contrast, in only 45% of the country-years where the corporate tax rate is unchanged is there a change to the corporate tax base. We also find limited evidence for a tendency towards tax reforms that simultaneously lower the corporate tax rate and broaden the corporate tax base. When the corporate tax rate decreases, this is accompanied by measures that broaden the tax base 37% of the time, and accompanied by measures that narrow the tax base only 26% of the time.

To explore the potential importance of accounting for concurrent changes in aspects of corporate tax bases, we next re-consider the question of how responsive corporate tax revenues are to the rate of tax applied by incorporating our new measures of the corporate tax base. In the past decade, the elasticity of taxable income (ETI) with respect to the marginal tax rate has come to occupy a central role in the normative evaluation of income tax systems. We corroborate previous findings that the relationship between corporate tax rates and corporate tax bases implies a revenue-maximizing corporate tax rate in the mid-30s when using the canonical specification used in previous studies (e.g., Clausing (2007)). When we control for time-invariant unobserved heterogeneity (as some earlier literature does), the statistical significance of the relationship between the corporate tax rate and corporate tax revenues is attenuated and sometimes eliminated; the implied revenue-maximizing corporate tax rate increases dramatically. We add a composite measure of the breadth of the corporate tax base based on our new data and find that this measure is not itself a statistically significant determinant of corporate tax revenues, and its inclusion does not substantively impact the magnitude of the estimated relationship between corporate tax rates and corporate tax rev-

enues. Adding our multi-dimensional measures of the corporate tax systems separately does, however, attenuate the relationship between corporate tax rates and corporate tax revenues.

The difference in impacts on the estimated relationship between corporate tax rates and tax revenues when including a composite tax base measure compared to including our 12 tax base measures separately suggests that the definition of the corporate tax base is indeed important, but perhaps not sufficiently captured in our extensive margin measures. Our new measures of the corporate tax base are imperfect because they only measure changes to the corporate tax base on the extensive margin; we know whether a given aspect was changed but not how much it changed. Constructing multi-dimensional intensive margin measures is a difficult, and perhaps infeasible, task as it would require defining a consistent method of measuring myriad tax preferences across countries. To this aim, several papers have constructed intensive margin measures for some aspects of the corporate tax base: depreciation allowances (Devereux, Griffith and Klemm 2002), thin capitalization (Blouin, Huizinga, Laeven and Nicodeme 2014), and transfer pricing regulations (Lohse, Riedel and Spengel 2012). Nevertheless, our new database provides an important step towards incorporating a more comprehensive measure of the vector of corporate tax instruments that can be used to assess the consequences of the corporate tax system.

2 Data

2.1 New data on tax base changes

We focus on experiences of developed countries over time using data on 30 OECD countries.[1] The data innovation of this project is the systematic documentation of changes in the breadth and nature of countries' corporate income tax bases. We hand-collect these data from the

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[1]The countries are Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

International Bureau of Fiscal Documentation's (IBFD) Annual Report publications, which provide concise summaries of important tax policy changes in several countries. We use publications from 1980 through 2004, so we study 750 potential country-year combinations when corporate tax base measures are included in the analysis.[2]

From the descriptions of tax policy changes, we code changes to several aspects of the corporate tax base. We assign noted changes in the tax base into one of the following twelve categories:

1. the research and development tax credit (R&D credit)

2. credits for foreign taxes paid

3. the tax treatment of foreign companies, such as credits or other incentives to attract foreign investment

4. policies that target evasion or avoidance by companies

5. investments credits or other tax incentives to promote investment

6. accelerated depreciation or other depreciation allowances

7. other tax rates that may affect the corporate tax base, e.g., net worth tax on corporations or extraordinary profits tax

8. loss carry-forward rules

9. loss carry-back rules

10. thin capitalization rules

11. controlled foreign company (CFC) legislation

12. other changes to the corporate tax base

An appendix to the paper provides a detailed explanation of how we have mapped the IBFD descriptions of tax policy changes into our twelve indicator variables.

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[2]These publications were produced annually from 1965 through 2002 and then in 2004. We utilize publications beginning in 1980 to focus on the time period that have been used in previous cross-country analyses of the relationship between corporate tax rates and corporate tax revenues. The 750 figure is a strictly upper bound on the number of country-years available. These measures are all set to zero in years prior to the existence of countries, when applicable. Because there are no corporate tax rate or revenues data for these country-years, these observations are not included in our analysis of the relationship between corporate tax rate and tax base changes or in any of the regression analysis.

For all of our tax base measures, we code a change that broadens the tax base system (defined as increasing tax revenue holding constant the statutory tax rate, other tax base aspects, and corporate behavior) as +1 and we denote a change that shrinks the tax base as -1. There are a few cases when in the same year there are several changes to the same tax base measure. For example, there may be two policies that are aimed at reducing tax avoidance behaviors. In these instances, we do not adjust our measurements beyond the +1 and -1 schematic. For each of our individual measures, there were no instances of counteracting policies (e.g., a year in which the R&D credit was made more generous accompanied by another policy that reduced the generosity of the R&D credit), so that our methodology can always be applied in a straightforward way.

2.2 Statutory rates and other data

Although we only have information on our corporate tax base measures through 2004, for comparison with previous analyses we collect data for 1980 through 2008 for the other variables. Summary statistics of these non-tax base variables are presented in Table 1.

Data on statutory corporate tax rates come from the OECD Tax Database for years 1981-2008 and supplemented with the University of Michigan World Tax Database for 1980 and some missing observations. These data refer to the top marginal income tax rates on domestic corporations at the central government level. Where a surtax applies, we use the statutory corporate rate exclusive of a surtax. Corporate income tax revenues as a fraction of GDP are collected from the OECD Revenue Statistics database. The revenues data refer to central government collections only. We collect information on several other aspects of taxation systems. Top personal income tax rates at the federal level are collected from the OECD Tax Database for years 1981-2008. We supplement these with personal tax rate data from the World Tax Database for 1980. These are the highest statutory marginal tax rates and, as with corporate tax rates, refer to central government taxes only. To control for the incentive to shift corporate income across countries, for each country in each year we compute the

GDP-weighted average of corporate tax rates in the other countries that are included in this study.[3] We construct an indicator variable that equals one if the country uses a worldwide system for taxing corporations, and zero if the country uses an exemption system using various publications of PricewaterhouseCoopers' *Corporate Taxes: A Worldwide Summary.*

Data on the present discounted value of depreciation allowances for an investment in plant and machinery (PDV of allowances) are available from the Institute for Fiscal Studies and cover a panel of 16 countries, all of which are included in this study, from 1979 through 2005.[4] Foreign direct investment data are obtained from the United Nations Conference on Trade and Development Statistics Database. The database contains data on inward and outward foreign direct investment stocks and flows.[5] We obtain information on GDP, GDP per capita, GDP growth rates, population growth rates, the proportion of the population residing in urban areas, and unemployment rates from the World Bank's World Development Indicators Database. GDP is reported in current U.S. dollars.[6] We also collect GDP in local currency to compute the corporate profit rate and the corporate share.

3 Do corporate tax bases change when corporate tax rates change?

In this section, we provide information on the nature of changes to the corporate tax rate and corporate tax base. Because comprehensive measures of the corporate tax base have not heretofore been available, previous analyses have had to rely on imperfect proxies for the tax base, if they address the issue at all. Our new corporate tax base measures allow us to examine this relationship in greater detail than has been previously possible.

To begin, Table 2 provides country-year counts for each of the twelve categories of tax

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[3]The contemporaneous GDP is used for these calculations.

[4]A description of the PDV of allowances data can be found in Devereux et al. (2002). Updated versions of the data used in Devereux and Griffith (2003) are available at http://www.ifs.org.uk/publications/3210.

[5]These data are available at http://unctadstat.unctad.org.

[6]These data are available at http://data.worldbank.org/indicators.

base changes separately for base broadening and base narrowing changes. Overall, changes to the corporate tax base are a fairly frequent phenomenon. There was at least one base change in 44% of all country-years, a total of 331. Because there can be more than one base change for a country in a given year, there are 531 changes to an aspect of the corporate tax base. The majority of these changes broadened the tax base (302, or 56.9% of tax base changes), but there are also substantial occurrences of narrowing the base (229, or 43.1%, of tax base changes).

Tabulations of country-years by the number of changes to the corporate tax base, broken down by base-broadening and base-narrowing measures, are provided in Table 3. The great majority of tax base changes contain only base-broadening or base-narrowing measures, but not both: Of the 331 country-years where there was any tax base change, 269 contained only tax base changes in one direction (161 country-years featured only base broadeners, and 108 featured only base narrowers).[7] There are 62 country-years when a country simultaneously enacts both a base broadener and a base narrower, so we are unable to determine the net impact of these policies to the corporate tax base with our binary measures.

Table 4 provides tabulations of tax rate changes and tax base changes by country between 1980 and 2004. Because we need two consecutive years of information to compute corporate tax rate changes, there is a maximum of 24 years per country for which we have information on changes in corporate tax rates. The IBFD Annual Reports provide information on changes to the definition of the corporate tax base for each year, and so there is a maximum of 25 years of data per country. All countries in our sample have changed their top statutory corporate tax rate and made some change to the corporate tax base at some point over the course of our sample period. Thus, there is significant variation in both corporate tax rates and tax bases across most countries, rather than these changes being concentrated in only a few countries.

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[7]Table 3 shows that in 419 country-years there was no base change, so 750-419=331. The number of country-years with base changes in only one direction is the sum of base changes counts in the first row and first column, less the number of instances with no base change. Only base narrowers occur in 80+19+7+2 = 108 instances, and only base broadeners occur in 118+36+7 = 161 instances.

Of particular interest is the relationship between the timing of tax rate changes and tax base changes. Table 5 provides a cross-tabulation of corporate tax base changes by the direction of corporate tax rate changes. First, consider the middle panel that presents aggregate measures of changes to the corporate tax base. Tax rate changes occurred in 171 country-years (26% of the 656 country-years for which we have two consecutive years of corporate tax data). Tax rate decreases (134 country-years) far outnumber tax rate increases (37 country-years) observed. The predominance of rate cuts (78%) is consistent with the well-documented trend toward declining corporate statutory rates over this period (e.g., Clausing (2007), Becker and Fuest (2011)). We document 309 country-years when there was any change to the corporate tax base.

Most of the tax system changes that occurred over this period consisted of a change to the base with no rate change (219 country-years), but there are also 81 country-years with only a rate change.[8] There are 90 country-years when there both the tax rate and the tax base changes. Because countries can implement polices that both narrow and broaden the corporate tax base in the same year, there are 104 different combinations of tax rate and tax base changes. Changes to the tax base are more likely to occur when there are also changes to the tax rate, relative to when there are no rate changes. About 53% (71 out of 134) of the corporate tax rate decreases and 51% (19 of 37) of the corporate tax rate increases were accompanied by some change to the corporate tax base. In contrast, some kind of base change occurred in only 45% (219 out of 485) of the country-years when there was no rate change.

Of the 104 instances when both the tax rate and base changed, the most prevalent combination was lower-the-rate, broaden-the-base (49 country-years), followed by lower-the-rate, narrow-the-base (35), raise-the-rate, broaden-the-base (14), and lastly raise-the-rate, narrow-the-base (6). These statistics make clear that both tax rate increases and tax rate decreases were more likely to be accompanied by base broadening, rather than base narrowing, mea-

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[8]This finding is consistent with the conclusion of Becker and Fuest (2011), where the present discounted value of depreciation allowances is the only measure of the tax base considered.

sures. A t-test on the equality of means reveals that, conditional on there being a decrease in the corporate tax rate, base-broadening measures are more likely than base-reducing measures at a 10% confidence level. Thus, on average there is a tendency for base changes to offset, rather than reinforce, the revenue effects of tax rate changes, at least within the same year. This result is consistent with the conventional wisdom that broaden-the-base, lower-the-rate reforms have predominated in recent decades. But, our new measures show that this policy was by no means universal. The top panel of Table 5 shows some interesting patterns for certain base changes. For example, a crackdown on evasion is much more likely to occur when the rate falls (18%, or in 24 of the 134 years where there is a tax rate decrease) than when the rate increases (8%, or 3 of the 37 years where there is a tax rate increase), but most of all when the rate is unchanged (27%). Tax rate decreases are never associated with extensions to the generosity of the R&D credit, accelerated depreciation allowances or loss carry back or carry forward allowances, each of which would be associated with a narrowing of the corporate tax base.

To further examine the relationship between tax-base-broadening measures and tax rate changes, we estimate a linear probability model of the following form: $I(BaseBroadened = 1)_{it} = \gamma_1 I(\Delta\tau < 0)_{it} + \gamma_2 I(\Delta\tau = 0)_{it} + \mu_t + \varepsilon_{it}$, where $I(\Delta\tau < 0)$ is an indicator variable for there being a tax rate decrease and $I(\Delta\tau = 0)$ is an indicator variable for there being no tax rate change. The omitted category is when corporate tax rates increase. We also estimate this model where the dependent variable is an indicator variable for a tax system change that narrows the corporate tax base definition, $I(BaseNarrowed = 1)_{it}$. We estimate these equations for aggregate measures of the corporate tax base, where the aggregate base broadening (narrowing) measure equals one if any of the corporate tax base components was broadened (narrowed).

Table 6 provides the estimated coefficients from these models. We learn from the first column that, relative to years when the corporate tax rate increases, tax base broadening measures are 26% more likely to occur when the corporate tax rate decreases and nearly

20% more likely to occur when the corporate tax rate remains unchanged. This corroborates the impression from Table 5. Similarly, we find that base narrowing measures are more likely to occur in years when the corporate tax rate decreases relative to years when the corporate tax rate increases, in this case by only 16%. In regression results not shown, we also estimate this model for each individual tax base measure separately. While some tax-base indicators do not have enough variation to compellingly estimate these models, some specific tax base measures are somewhat more likely to be broadened when the corporate tax rate decreases. Specifically, these are policies to curb tax evasion or avoidance, the investment tax credit, and thin capitalization rules. When the corporate tax rate is reduced, accelerated depreciation allowances are more likely to be made more generous and other tax rates that affect corporate tax revenues are more likely to be reduced, relative to years when the corporate tax rate increases.

We also would like to examine the longer-run tendencies in the types of tax reforms that countries have undergone. First, the bottom panel of Table 5 depicts similar information as the middle panel, but considers whether there were tax base changes of a particular direction within three years of a change in the corporate tax rate. A similar pattern emerges. We again see a tendency for corporate tax rate decreases to be accompanied by base-broadening measures more often (63%, or in 85 of 134 occurrences, of the time) than base-narrowing measures (51%, or in 68 of 134 occurrences, of the time).[9]

Next, Figure 1 depicts one aspect of the relationship between changes in the corporate tax rate and changes in the breadth of the corporate tax base. Here, the change in corporate tax rates is computed as the change in the corporate tax rate between the last year and the first year in which data are available. The net change in the corporate tax base sums the various changes in our tax base measures between 1980 and 2004. For example an overall

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[9]A test on the equality of means shows that within three years of a tax rate change, base-broadening measures are almost 13% more likely than base-narrowing measures when the corporate tax rate falls, and 3% more likely when the corporate tax rate rises. Both differences are statistically significant at the 10% level. Thus, the tendency for policies with offsetting revenue effects is persistent over a longer period, as well.

positive value indicates that over this period, there were more measures that broadened the corporate tax base than measures that narrowed it. The majority of the countries in our sample are above the zero horizontal line and to the left of the zero vertical line, indicating that most countries both lowered their corporate tax rates and on average engaged in tax base-broadening measures.

As supplemental evidence of the relationship between changes in corporate tax rates and corporate tax revenues, we consider the alternative proxy for the corporate tax base used in Devereux (2007), the change in the present value of depreciation allowances (PDV of allowances). The PDV of allowances corresponds to one of our tax base indicator variables, changes to tax depreciation allowances. Figure 2 depicts the relationship between the change in the corporate tax rate and (-1 times) the change in the PDV of allowances between the last year and the first year in which the data are available.[10] We define the PDV of allowances measure so that increases along the y-axis refers to a broadening of the corporate tax base as in Figure 1. This figure shows that the majority of countries have experienced decreases in the corporate tax rate along with a broadening of the corporate tax base (in this case, through a decrease in the PDV of allowances).

In sum, our new database on corporate tax base changes provides further insights into the nature of policy changes to the corporate tax system. We find evidence that the policies of OECD countries from 1980 through 2004 have mostly been of the lower-the-rate and broaden-the-base variety, but there has been substantial variation among countries. This evidence raises doubts about previous research that estimates the impact of the corporate tax rate on corporate behavior, or tax revenues, without taking such correlations into account. In particular, if not appropriately accounted for, we should be concerned that the impact of changes to the tax base will in part be reflected in the estimated tax rate effects. We turn

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[10]This figure provides complementary evidence to Figure 1 in Becker and Fuest (2011), which plots year-to-year changes in corporate tax rates and the PDV of allowances for 19 OECD countries between 1982 and 2003 using the same source data. Becker and Fuest (2011) show that the majority of tax reforms in these country-years resulted in a decrease in the corporate tax rate, a decrease in depreciation allowances (i.e., a broadening of the corporate tax base), or both.

to this issue in the next section.

4 An application to the determinants of corporate tax revenues

4.1 Framework

In this section we examine the implications of ignoring changes in non-rate aspects of tax system in one specific context: the determinants of corporate tax revenues. Consider a single-period, closed-economy model where the corporate tax schedule has a single rate (τ), so that tax revenue (R) is simply proportional to taxable income (Y). Taxable income depends in two ways on the non-rate aspects of the tax system (the vector N) that define the tax base. The first is a mechanical relationship - revenues change when the base changes absent any behavioral response. Second, corporate decisions (the vector D) may be affected by the non-rate aspects of the tax system via incentive effects; the decisions themselves are generally a function of both τ and N. These decisions include real ones such as investment, but also income shifting, tax avoidance and tax evasion. Thus we can write:

$$R = \tau Y(N, D(\tau, N)). \tag{1}$$

The value of N may also affect $dD/d\tau$, and therefore $dY/d\tau$, and in turn, the elasticity of taxable income, which is usually defined as $\frac{dY}{d(1-\tau)}\frac{(1-\tau)}{y}$. Note, for further reference, that $\frac{dR}{d\tau} = Y + \tau\frac{dY}{dD}\frac{dD}{d\tau}$ and that $\frac{dR}{dN} = \tau[\frac{dY}{dN} + \frac{dY}{dD}\frac{dD}{dN}]$.

A country's statutory rate could affect several categories of decisions, and thereby affect taxable income and revenues. One obvious candidate is taxable income shifting. This shifting could be from high tax-rate countries to low tax-rate countries, reducing tax revenues in the former, but increasing it in the latter. A low rate of corporate tax relative to personal income tax may also encourage businesses to take incorporated form, making them liable

to corporate taxes in addition to personal income taxes, and otherwise shift taxable income into the corporate tax base, as examined by Gordon and Slemrod (2002).

The vector of the non-rate aspects of the tax system, N, includes elements that are usually characterized as affecting the tax base. One might distinguish two types of base-related tax system aspects: those that provide behavioral response opportunities, and those that do not. An example of the former is the domestic production deduction, which allows for a reduction in net income for certain domestic business activities and thus provides an incentive to expand lower-taxed domestic activity at the expense of other activities. Another example is accelerated depreciation. Because depreciation for tax purposes does not equal economic depreciation, the effective tax rate on new investment varies across capital assets and a change in the statutory tax rate will affect the effective tax rate differentially. Only the former would be expected to affect the elasticity of response with respect to the statutory rate, by broadening the range of ways in which the tax base could be reduced in response to a higher statutory rate.

4.2   Previous research

Several recent papers have attempted to estimate the elasticity of corporate tax revenues - and by implication, the elasticity of the corporate tax base - with respect to the statutory rate.[11] These studies focus on developed countries and generally begin with a regression of corporate tax revenues[12] as a fraction of GDP[13] on the corporate tax rate, the corporate tax

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[11]In a similar spirit, Gruber and Rauh (2007) estimate the impact of the corporate tax rate on the level of corporate taxable income for publicly traded U.S. firms. Using Compustat data, they implement an empirical design that is motivated by the elasticity of taxable income literature for individual income taxation, and find an elasticity of -0.2. In a similar vein, Devereux, Liu and Loretz (2014) estimate this elasticity for UK firms using administrative tax data; Patel, Seegert and Smith (2015) estimate this elasticity for US firms using administrative tax data.

[12]An alternative is to investigate the determinants of the tax base, rather than tax revenue. The decisive problem with this approach is that the base is not known and can be approximated as R/τ, which imparts potentially serious division bias to the extent of measurement error in τ.

[13]These analyses, as ours that follows, ignore the possibility that tax rate and tax base changes may affect GDP (indeed that is often their motivation), so that the estimated effects may not reflect solely the impact of the explanatory variables on tax revenues. Nor does this methodology allow us to parse out the effects that operate via the incidence of the tax changes, e.g. that corporate taxes may reduce wage income if they

rate squared and year fixed effects to allow for worldwide macroeconomic conditions that affect all countries' corporate tax system outcomes. Estimates based on this regression imply a revenue-maximizing tax rate ranging from the mid-20s to mid-30s.

Clausing (2007) uses data on 29 OECD countries from 1979 to 2002 and finds a substantial negative response of the tax base to rate changes in her baseline model. The baseline estimate implies a revenue-maximizing corporate tax rate is 33%, though estimates are quite sensitive to the set of included controls.[14] Brill and Hassett (2007) estimate a related model, but without year fixed effects, using data on 29 OECD countries between 1980 and 2005 and find similar results. Devereux (2007) uses data for 20 OECD countries from 1986 to 2004, and obtains similar results when estimating a model similar to Clausing (2007). He develops an alternative approach that builds from a profit-maximizing firm's decisions, which suggests that a preferred approach is to estimate the relationship between the log of corporate tax revenues on the log of the corporate tax rate, and other controls. When estimating this specification, he finds only weak evidence of any relationship between corporate tax revenues and corporate tax rates.

Despite using panel data, these studies critically omit country-specific fixed effects, which would control for time-invariant aspects of the non-rate aspects of the corporate tax system that may differ substantially across countries. This is important because unobserved heterogeneity may impart bias to the previous analyses. There are several potential sources of heterogeneity. For example, a reduction in the corporate tax rate may induce a larger behavioral response by corporations in a country where the detection of tax avoidance is relatively sophisticated than a similar reduction in a country where firms are able to employ tax avoidance schemes with relative ease.[15] Other examples include the willingness to rely on corporations for tax revenues, the effectiveness of tax collection agencies, and differences

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reduce the domestic capital stock.

[14]For example, the estimates in Clausing (2007) imply a revenue-maximizing tax rate of 57% for relatively large, closed countries, such as the U.S.

[15]For example, Slemrod and Gillitzer (2014) provide a detailed exposition regarding the importance of the administration of the tax system and the extent of tax evasion in the discussion of optimal taxation.

in data collection systems. Some of these omitted variables likely affect both corporate tax revenues and corporate tax rates, rendering the previous estimates biased and inconsistent. While acknowledging this issue, both Clausing (2007) and Devereux (2007) argue that when country-specific fixed effects are included, insufficient within-country variation remains to identify tax rate effects. Notably, Gravelle and Hungerford (2007) find that when they add country-specific fixed effects to this type of specification, corporate tax rates are no longer statistically significant predictors of corporate tax revenues. This finding confirms that unobserved heterogeneity is indeed quite important when considering the impacts of the corporate tax rate on corporate tax revenues using a cross-country analysis. Moreover, and quite strikingly, their results suggest that we cannot reject the null hypothesis that changes in corporate tax rates *have no effect on* changes in corporate tax revenues.

Even controlling for time-invariant unobserved heterogeneity, omitted-variable bias will remain if non-rate but revenue-relevant aspects of the corporate tax system that are not included as explanatory variables vary over time. As Section 3 demonstrates, changes to the corporate tax rate often are accompanied by changes to the corporate tax base, and both of these changes affect corporate tax revenues.[16] Without accounting for tax base changes, the joint effect of changing rates and bases is attributed to tax rates alone, which in general will lead to biased estimates of the effect of corporate tax rates on corporate tax revenues. Moreover, the implied revenue-maximizing tax rate from these analyses would be biased toward zero. To address this issue, some of the previous studies include proxies for the tax base, using the size and profit rate of the corporate sector in the case of Clausing (2007), and a measure of depreciation allowances in the case of Devereux (2007).[17] We would argue that these measures are not sufficient and, in the analysis that follows, we revisit these analyses by making use of our new variables to explicitly account for changes to the corporate tax

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[16]Robinson and Slemrod (2012) investigate this issue in the context of individual income taxation.

[17]Clausing (2007) proxies for the size of corporate profits with the GDP growth rate and the unemployment rate, and proxies for the share of the corporate sector with GDP per-capita. In another specification, she includes corporate share of GDP, corporate profitability, and the system for taxing worldwide income to account for the tax base. Devereux (2007) uses a more direct measure of the corporate tax base–the present discounted value of tax depreciable allowances per dollar of investment in plant and machinery.

base.

4.3   Replication of previous studies

To provide a comparable baseline for our analysis, we begin by estimating the canonical specification featured in previous studies:

$$R_{it} = \beta_0 + \beta_1 \tau_{it} + \beta_2 \tau_{it}^2 + \Gamma X_{it} + \mu_t + \varepsilon_{it}, \tag{2}$$

where R_{it} is the ratio of corporate tax revenues to GDP, τ_{it} is the top statutory corporate tax rate, X_{it} are control variables, μ_t are year fixed effects, and i denotes country and t denotes year.[18] In the formulation presented in Equation (2), the impact of a change in corporate tax rates on corporate tax revenues is given by:

$$\frac{dR}{d\tau} = \beta_1 + 2\beta_2 \tau. \tag{2b}$$

This relationship can equivalently be expressed in terms of our theoretical framework presented in Section 4.1 by: $\frac{dR}{d\tau} = Y + \tau \frac{dY}{dD} \frac{dD}{d\tau}$.

We first replicate the key results of Clausing (2007) by estimating equation (2) using OLS. Results are shown in column (1) of Table 7. This specification corresponds to column (4) of Table 4 in Clausing (2007), and includes the most generous number of her controls.[19] We report standard errors that are clustered at the country level, in parentheses, to allow for arbitrary within-country serial correlation. Corporate tax revenues are likely serially correlated within a country due to trends in economic growth and the corporate tax climate, among other reasons, and failing to appropriately account for this serial correlation will

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[18]Following the previous literature, we do not pursue the potential endogeneity of tax policy, nor attempt to distinguish business-cycle-exogenous policy changes, as in Romer and Romer (2014), for example.

[19]For ease of reading, the corporate tax rate squared is divided by 100 in the regressions. In the baseline model that includes no other controls, we estimate that $\hat{\beta}_1 = 0.23$ (se = 0.04) and $\hat{\beta}_2 = -0.35$ (se= 0.08), which gives an implied revenue-maximizing rate of 33.0% (se=2.22). There are 640 observations and standard errors are clustered at the country level.

typically lead to invalid (usually underestimated) standard errors of the parameter estimates. However, we also report (non-clustered) robust standard errors, as is done in Clausing (2007), in square brackets, for comparability. We provide a similar replication exercise of Devereux (2007) in Appendix B.

Our OLS results are qualitatively very consistent with Clausing (2007), although the point estimates differ somewhat due to differences in sample size, years considered, and data sources. The estimates imply a concave relationship between corporate tax revenues and corporate tax rates. This relationship is highly statistically significant, although not surprisingly we find that allowing for serial correlation substantially increases the standard errors. The concavity of this relationship implies that the marginal effect of tax rates on revenues positive until some revenue-maximizing tax rate is reached, and then becomes negative. The bottom row of Table 7 presents the marginal effect of tax rates evaluated at the sample mean of tax rates in the estimation sample and for the baseline case where the "Big" and "International" dummies are set equal to zero; the marginal effect is -0.01, suggesting that on average, countries lie beyond the revenue-maximizing tax rate. Column (1) of Table 8 presents the implied revenue-maximizing corporate tax rate for different combinations of the "Big" and "International" dummy variables based off of this specification. The table shows that the implied revenue-maximizing corporate tax rate for a small and less open country, for example, is about 32.9 percent, compared to 36.4 percent in Clausing (2007). Large and less open countries, such as the U.S., have the highest implied revenue-maximizing rate, at 38 percent, compared to 57 percent in Clausing (2007). Non-clustered standard errors suggest that all the included factors are statistically significant determinants of corporate tax revenues, closely mimicking the results in Clausing (2007); clustered standard errors, however, provide little evidence that the other included factors are statistically related to corporate tax revenues.

In column (2), we repeat this replication but now include one additional variable, the average corporate tax rate for the other countries in our sample, to account for potential

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income shifting responses across countries' corporate tax bases.[20] In this and all remaining specifications, standard errors are clustered at the country level. The results support that an increase in the corporate tax rate in other countries corresponds to more corporate income reported in the home country. The magnitudes and statistical significance of parameter estimates for the other variables are consistent with the specification that excludes other countries' corporate tax rates. The exception is now the interaction between the indicator variable for a country being big and the corporate tax rate measures are statistically significant at least at the 10% level. The implied revenue-maximizing rates, presented in column (2) of Table 8 are all somewhat increased in this specification. Notably, the implied revenue-maximizing tax rate for a large, less open country, such as the United States, increases from 38 to 47 percent when we control for the weighted-average of other countries' corporate tax rates.[21]

Next, we account for unobserved time-invariant heterogeneity. We remove country-specific fixed effects using two alternative methods: by including country-specific fixed effects (FE), and by estimating equation (2) in first-differences (FD).[22] Results from the FE and FD specifications are presented in columns (3) and (4) of Table 7, respectively.[23]

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[20]See Riedl and Rocha-Akis (2012) for recent empirical support for including other countries' tax rates in such an equation. Our ability to identify income shifting across countries is limited because we include only the tax rates for the other countries included in this study, as is done in the previous literature. Thus, this measure does not capture incentives to shift to tax havens outside of our sample of countries. Desai, Foley and Hines (2003) provide evidence on the behavioral responses of U.S. firms' foreign direct investment to international tax rates and Altshuler and Grubert (2004) provide evidence on responses in a larger set of countries. Both report a large tax elasticity of measured foreign investment. Desai, Foley and Hines (2006b) develop a model where tax havens may increase business activity in non-haven countries, with empirical support in Desai, Foley and Hines (2006a).

[21]As in the previous specification, we provide the marginal effect of tax rates on tax revenues evaluated at the sample mean of the estimation sample and for the baseline case. The marginal effect is now much closer to zero, reflecting that the sample mean is quite close to the implied revenue-maximizing rate for small and less open countries.

[22]The FE and FD estimators are both estimation strategies for removing country-specific fixed-effects, either through first-differencing (FD) or through mean-differencing (FE). In the simple case when there are only two time periods, these estimators are equivalent. With more than two time periods, as in our case, these estimators differ in their assumptions over the idiosyncratic error term.

[23]With respect to our clustered standard errors, serial correlation will matter for computing standard errors in the FD specification if *differences* in corporate tax revenues are serially correlated. For these specifications, clustered and non-clustered standard errors produce very similar results, and statistical inference is effectively unchanged.

In the FE specification, the magnitude of the relationship between the corporate tax rate and corporate tax revenues is somewhat attenuated, suggesting that unobserved cross-country factors are important in estimating the effect of corporate tax rates on corporate tax revenues using cross-country data.[24] The implied revenue-maximizing rates, which are presented in column (3) of Table 8, are considerably higher when country-specific fixed effects are included. The implied revenue-maximizing rate is even greater than 100 percent for large, less open countries, although the standard error on this estimate is quite large.[25] The marginal tax effect, again evaluated at the sample mean and for the baseline case, is now positive, providing complementary evidence of the now attenuated relationship between the corporate tax rate and corporate tax revenues: the average corporate tax rate in our sample is below the implied revenue-maximizing rate of 57% for the baseline case. None of the other covariates is statistically significant at the 5% level. There is, however, weak evidence of income shifting, both between the individual and corporate tax bases within in a country and between corporate tax bases across countries.

In the FD specification, the estimated tax effects are much smaller and are no longer statistically significant. The FD specification loses several observations because first-differencing requires that we have data for all included variables in consecutive years for that observation to be included. We also lose the first observation for each country. The implied revenue-maximizing rates generally increase even further, and they are always greater than 64 percent. As with the FE specification, the marginal tax effect evaluated at the sample mean for the baseline case is positive, suggesting that the average corporate tax rate in our sample lies below the implied revenue-maximizing tax rate. The unemployment rate and GDP growth rate are now negatively correlated with changes in corporate tax revenues.

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[24]We do not believe there is no insight at all to be gained from cross-country comparisons. There is no doubt, for example, that Ireland's relatively low corporate tax rate is partly responsible for its large corporate tax revenues relative to its GDP. We leave for future research the appropriate way to learn from this with minimal bias in estimated causal relationships.

[25]In regressions not shown, we find that when we restrict our attention to the specification in Gravelle and Hungerford (2007) (i.e., years prior to 2003 and using the variables included in their analysis), the relationship between corporate tax rates and tax revenues is no longer statistically significant. The point estimate of the revenue-maximizing corporate tax rate from these specifications is between 37 and 53 percent.

The vast differences between the FE and FD specifications suggest that the included covariates are correlated with the error term.[26] In particular, our analysis in Section 3 suggests that changes to the corporate tax base, which are subsumed in the error term, and the corporate tax rate co-vary contemporaneously. In fact, in results not shown, we reject the null hypothesis of strict exogeneity at the 5% level.[27] With contemporaneous correlation, the FD and FE estimates described above will be inconsistent and have different probability limits. In the next section, we include our new measures of the corporate tax base to control for a likely source of this endogeneity: the tendency of countries to implement policies that simultaneously change the corporate tax rate and the definition or enforcement of the corporate tax base.

4.4 The impact of the corporate tax base vector

As we have previously argued, the definition and enforcement of the corporate tax base affects corporate tax revenues. However, because the base is multi-dimensional, represented by the vector N in Section 3, and legislation that determines these factors is highly complex, it is difficult to obtain a summary measure of the corporate tax base and its changes over time; perhaps for this reason it has been largely ignored in empirical analyses. Moreover, we have documented that elements of the corporate tax system vector often change, so that even after accounting for persistent differences in tax policy across countries via a FE or FD specification, estimates of the tax-rate responsiveness of corporate tax revenues are likely to remain biased. Our new measures of corporate tax base changes allow us to provide estimates of the relationship between corporate tax revenues and corporate tax rates that more plausibly control for changes to the corporate tax base.

Our new tax base measures reflect *changes* in the corporate tax base, rather than measuring the tax base itself. That is, when the R&D tax credit amount is increased, for example,

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[26]Another potential reason for the difference in point estimates between the FE and FD specifications is that first-differencing amplifies the variation in highly variable data.

[27]This test estimates the following regression, $\Delta y_t = \Delta x_t \beta + w_t \gamma + \Delta u_t$, where w_t is a subset of the included covariates (excluding time dummies) and tests the hypothesis $\gamma = 0$.

the indicator variable for the change in the R&D tax credit is recorded as -1 in our data. Letting b_{it} denote a vector of indicator variables that identify changes to the tax base, we compute a vector of the cumulative value of our tax base measures from the beginning of the sample, B_{it}. Defined in this way, $B_{it} = \sum_t b_{it}$ and $\Delta B_{it} = b_{it}$. We include B_{it} in the FE specification, as follows:[28]

$$R_{it} = \beta_1 \tau_{it} + \beta_2 \tau_{it}^2 + \beta_3 B_{it} + \Gamma X_{it} + \mu_t + \delta_i + \nu_{it}. \tag{3}$$

While our new data allow us to now control for the presence of changes to the vector of tax instruments, they do not account for the *relative* importance of different changes to a given instrument over time nor of the various types of base broadeners in the absence of a defensible and data-feasible weighting approach that would apply across years and countries.

Table 9 presents results from FE regressions that include a composite measure of changes to the corporate tax base. This composite measure aggregates over the 12 specific tax base measures, and is included as B in equation (3). In column (2), we also include interactions between this composite measure and the corporate tax rate (and its square). Across both specifications, we find results that are very consistent with our FE specifications in Table 7. Surprisingly, the point estimates suggest that policies that broaden the definition of the corporate tax base are related to a decrease in corporate tax revenues, though the standard errors on this estimated parameter are large. The implied revenue-maximizing corporate tax rates based on the parameter estimates from these specifications are presented in columns (1) and (2) of Table 11. The rates presented in column (2) are evaluated with the cumulative tax base changes set equal to zero. Overall, these implied rates are qualitatively similar to those found in Table 8 when the aggregate tax base measures are not included.

To examine the impact of each of our new tax base measures separately, Table 10 presents regression results where we replace the aggregate tax base measure with our 12

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[28]If we were able to construct a continuous measure of the breadth of the corporate tax base, summarized by a single variable, b, we could alternatively include it directly in our FE regression, along with its interactions with the corporate tax rate variables.

newly-developed individual tax base measures.[29] This specification includes the covariates included in the previous specifications, but for brevity we do not report all of them. Parameter estimates on these unreported variables are generally consistent with the regressions including the aggregate tax base measure.[30] Controlling for changes in our tax base measures separately attenuates the magnitude of the estimated tax effects relative to the baseline FE specification (column (3) of Table 7). The implied revenue-maximizing corporate tax rates based on the parameter estimates from these specifications are presented in column (3) of Table 11. Including the individual tax base measures pushes up the implied revenue-maximizing rate for small, less open countries from 57 to 61 percent, and pushes down the implied revenue-maximizing rate for large, open countries from 56 to 50 percent. In addition, the standard errors on these implied revenue-maximizing rates are generally smaller than those obtained from the previous specifications.

Considering the impacts of the individual tax base measures, several interesting patterns emerge. Increased tax incentives for foreign firms (indicated by a decrease in the cumulative taxation of foreign companies measure) are associated with an increase in corporate tax revenues. This relationship is expected if investment incentives aimed at foreign companies are successful at attracting foreign investment, as many policy descriptions indicate as a goal. Somewhat surprisingly, measures aimed at curbing tax evasion and avoidance behaviors are associated with *decreases* in corporate tax revenues. Our best explanation for this result is that these measures are put in place during periods when corporate tax revenues are declining. Lastly, restrictions to the ability to carry back losses are associated with contemporaneous revenue decreases. This relationship is consistent with more generous carry-back loss rules used as an economic stabilizing tool, implemented at times when many firms have large losses. Each of these relationships is only marginally statistically significant at the 10% level; the remainder of the tax base measures are not statistically significant. All

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[29]As in the previous specification, our new data provide a more thorough analysis of the impact of the corporate tax system on corporate tax revenues; however, these specifications beg the question of comparability within a category across countries and years.

[30]The exception is that the unemployment rate is not statistically significant at the 10% level.

in all, our results suggest that the individual base measures do not have a strong contemporaneous relationship to revenues of the expected sign. As mentioned, this could be due to the endogeneity of the base changes, because many of these changes are not quantitatively substantial, or because the behavioral response does not occur immediately or has a perverse initial effect due to stimulating investment whose initial return is tax-favored.

In sum, including a cumulative tax base measure has little impact on the estimated relationship between corporate tax rates and corporate tax revenues; including each corporate tax base measure separately attenuates this estimated relationship, and some of the tax base measures are marginally statistically significant. Put together, our results suggest that the definition and enforcement of the corporate tax base is important, but that these are not well captured by our qualitative measures of the corporate tax base. Presumably, the impact of the corporate tax base would be better captured with quantitative measures of the corporate tax base.

5 Conclusions

In this paper we have compiled a new database that documents the occurrence of changes to key components of the corporate tax base definition and enforcement, and have documented the relationship between changes to the corporate tax rate and changes to the corporate tax base. To our knowledge, this is the first systematic analysis of this relationship. We discover that the conventional wisdom that tax rate decreases are generally accompanied by base-broadening reforms is evident, but not overwhelmingly, in the data.

Finding that changes to the corporate tax rate are often enacted simultaneously with changes to the corporate tax base, we re-estimate the relationship between the corporate tax rate and corporate tax revenues, taking into account changes to the corporate tax base. First, we find that correcting for cross-country heterogeneity that is time invariant attenuates the relationship between corporate tax rates and corporate tax revenues, and pushes up

the estimated revenue-maximizing rate implied from these estimates. Once we account for the simultaneity of changes to corporate tax rates or corporate tax bases by including our 12 new tax base measures in the estimating equation, the estimated tax effects are even more attenuated and the implied revenue-maximizing corporate tax rates generally are more precisely estimated. We find only weak evidence that several types of tax policies that affect the definition or enforcement of the corporate tax base are related to changes in corporate tax revenues.

Ideally, one would like to construct measures of intensive changes to the corporate tax base that are comparable across countries and include those as additional determinants of corporate tax revenues. Despite their limitations, our extensive margin measures of changes to the corporate tax base provides an informative step towards a better understanding of the interaction between corporate tax rate and tax base changes, and their implications for understanding the determinants of corporate tax revenues.

Figure 1: Change in corporate tax rates and change in corporate tax bases, 1980-2004

The figure shows the net change in the corporate tax rate and the net change in the tax base definition between 1980 and 2004. The net change in the corporate tax base is computed as the cumulative sum of changes to all of our 12 tax base measures documented in our tax base database.

Table 1: Summary statistics of non-base measures

Variable	Mean	Std. Dev.	Min	Max	N
Corp. tax revenues/GDP	2.55	1.51	0.12	12.76	779
Corporate tax rate	33.68	9.70	8.50	56.00	807
Personal tax rate	44.12	14.14	7.00	84.40	794
PDV of depreciation allowance	0.77	0.07	0.61	1.00	482
Worldwide tax system	0.53	0.50	0.00	1.00	870
GDP per capita	19,988	15,009	1,114	117,954	853
GDP growth rate	2.82	2.74	-14.57	11.50	843
Population growth rate	0.63	0.57	-0.60	2.53	870
Urban population percentage	72.73	11.58	42.80	97.36	870
Unemployment rate	7.30	4.01	1.50	23.90	745
FDI stock/GDP	0.39	0.96	0.00	10.08	787
FDI flow/GDP	0.05	0.31	-0.57	5.65	794

The table presents sample means, standard deviations, minimum values and maximum values for 30 OECD countries between 1980 and 2008. The final column presents the number of observations with non-missing information for each variable.
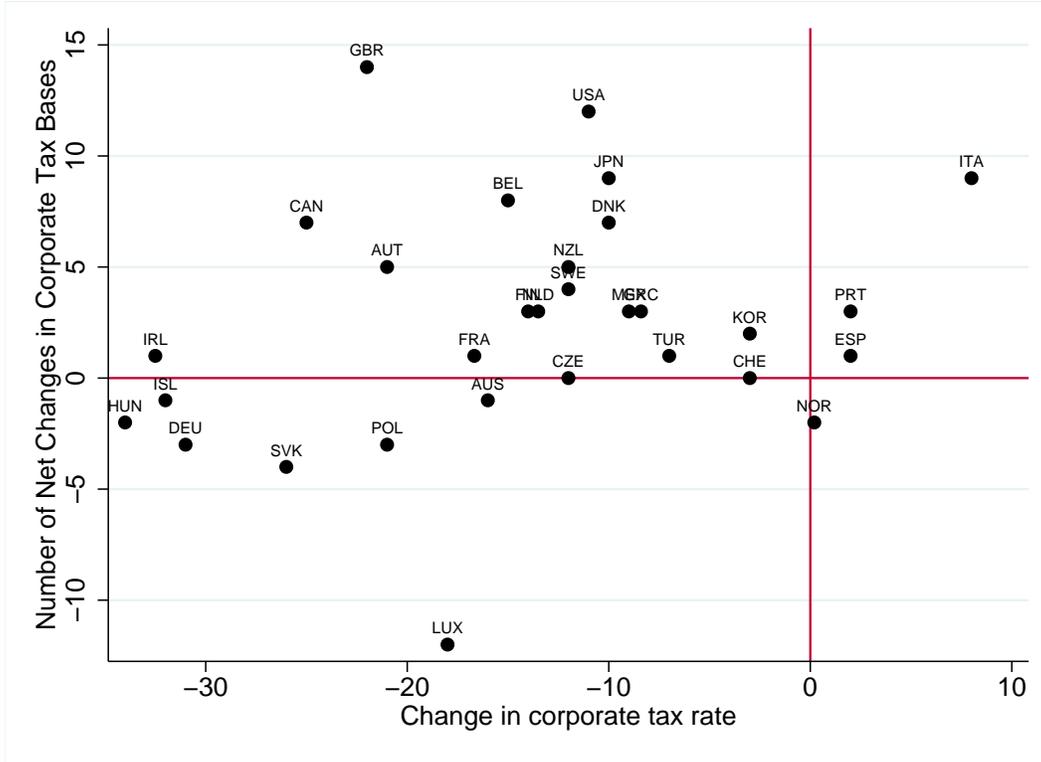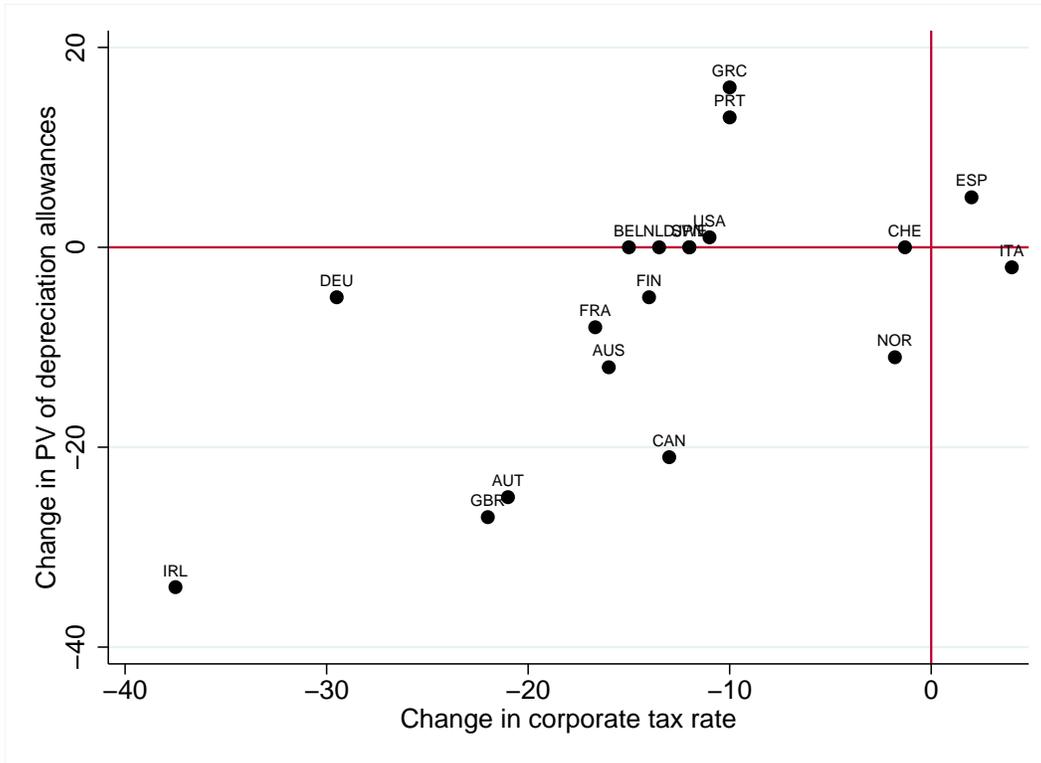
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Figure 2: Change in corporate tax rates and change in depreciation allowances, 1980-2008

The figure shows the net change in the corporate tax rate and the net change in the PDV of depreciation allowances between 1980-2008. This figure complements evidence presented in Figure 1 of Becker and Fuest (2011), which provides similar evidence on a country-year level.

Table 2: Frequency of corporate tax system changes (country-years), 1980-2004

	-1	+1	Total Changes	No Change
Evasion	0	105	105	645
Other rate change	45	40	85	665
Investment credit	50	20	70	680
Other broadening measures	21	47	68	682
Foreign company taxation	24	21	55	705
Accelerated depreciation	25	7	32	718
Foreign tax credit	20	10	30	720
Loss carry forward	19	6	25	725
Thin capitalization	0	22	22	728
CFC legislation	2	20	22	728
R&D credit	17	1	18	732
Loss carry back	6	3	9	741
Total	229	302	531	
Any base broadeners			223	
Any base narrowers			170	
Any base change			331	
No base change			419	

The table presents tabulations of extensive margin changes to 12 corporate tax base measures. A value of +1 indicates a change that has broadened the definition of the corporate tax base, while -1 indicates a change that has narrowed the corporate tax base. The top panel presents tabulations for each of the 12 tax base measures separately; the bottom panel tabulates instances when there are any instances of a change to the corporate tax base based on these measures. Some country-years have both base-broadeners and base-narrowers, so the number of country-years with any base change is less than the number of country-years with base-broadeners plus the number of country-years with base-narrowers.

Table 3: Frequency of country-years with base-broadening and base-narrowing measures, 1980-2004

Number of base broadeners	Number of base narrowers					At least one	Total
	0	1	2	3	4		
0	419	80	19	7	2	108	527
1	118	29	10	1	0	40	158
2	36	12	6	0	0	18	54
3	7	1	1	0	0	2	9
4	0	0	1	0	0	1	1
5	0	1	0	0	0	1	1
At least one	161	43	18	1	0	223 170	
Total	580	123	37	8	2		750

The table presents tabulations of the coincidence of tax base broadening changes and tax base narrowing changes across country-year pairs.

Table 4: Statutory tax rate and tax system changes, by country, 1980-2004

				Country-years							Counts	
Country	dt>0	dt<0	dt=0	Any base change	dB>0	dB<0	Only dB>0	Only dB<0	Both dBase>0 and dB<0	dB=0	Base broadeners	Base narrowers
Australia	2	4	18	17	12	11	6	5	6	8	18	19
Austria	1	1	22	14	10	8	6	4	4	11	16	11
Belgium	0	5	19	13	9	5	8	4	1	12	15	7
Canada	0	7	17	13	10	4	9	3	1	12	14	7
Czech Republic	1	6	6	8	4	4	4	4	0	17	5	5
Denmark	1	5	18	9	7	4	5	2	2	16	11	4
Finland	3	4	17	6	5	1	5	1	0	19	5	2
France	1	6	17	18	12	9	9	6	3	7	14	13
Germany	1	5	18	14	7	10	4	7	3	11	13	16
Greece	3	4	17	9	6	4	5	3	1	16	7	4
Hungary	0	4	11	14	8	9	5	6	3	11	13	15
Iceland	0	3	4	1	0	1	0	1	0	24	0	1
Ireland	1	11	12	10	6	5	5	4	1	15	6	5
Italy	3	3	18	18	16	9	9	2	7	7	19	10
Japan	2	5	17	16	12	7	9	4	3	9	19	10
Korea	1	4	19	11	8	6	5	3	3	14	10	8
Luxembourg	0	7	17	14	3	12	2	11	1	11	3	15
Mexico	1	9	14	12	8	4	8	4	0	13	10	7
Netherlands	0	4	20	13	10	8	5	3	5	12	14	11
New Zealand	2	1	21	10	8	3	7	2	1	15	8	3
Norway	6	1	17	5	2	4	1	3	1	20	2	4
Poland	0	7	6	9	4	7	2	5	2	16	5	8
Portugal	2	8	14	14	10	8	6	4	4	11	13	10
Slovak Republic	0	4	7	5	2	4	1	3	1	20	3	7
Spain	1	0	23	15	9	9	6	6	3	10	12	11
Sweden	1	3	20	12	8	5	7	4	1	13	9	5
Switzerland	0	2	22	0	0	0	0	0	0	25	0	0
Turkey	3	1	17	5	3	2	3	2	0	20	3	2
United Kingdom	0	8	16	16	14	3	13	2	1	9	17	3
United States	1	2	21	10	10	4	6	0	4	15	18	6
Total	37	134	485	331	223	170	161	108	62	419	302	229

The table presents tabulations of the number of tax rate changes and tax base changes that have occurred within a country between 1980 and 2004. The bottom row presents overall counts across all country-years. The tax base measures are presented as aggregate measures across all 12 tax base definitions that are included in the database. The tax rate data are described in Section III. Note that an observation requires that a country has information on tax rates and tax bases in two consecutive years.

Table 5: Frequency of tax base changes accompanying rate changes (country-years)

Change in corporate tax rate	Decrease		Increase		No change		Total	
Change in corporate tax base measure	-1	+ 1	-1	+1	-1	+1	-1	+1
R&D credit	2	0	0	0	14	1	16	1
Foreign tax credit	4	2	1	0	13	8	18	10
F Foreign company taxation	3	5	1	2	15	13	19	20
Evasion	0	24	0	3	0	73	0	100
Investment credit	10	4	1	0	37	15	48	19
Accelerated depreciation	6	2	0	0	18	5	24	7
Loss carry back	4	1	0	0	2	2	6	3
Loss carry forward	6	1	0	0	12	5	18	6
Thin capitalization	0	6	0	1	0	15	0	22
CFC legislation	0	6	0	1	2	13	2	20
Other rate change	10	3	2	5	30	25	42	33
Other broadening measures	6	14	1	3	13	30	20	47
Total	51	68	6	15	158	203	215	286

Change in corporate tax rate:	Decrease	Increase	No change	Total
Base broadened (+1)	49	14	151	214
Base narrowed (-1)	35	6	115	156
Any base change	71	19	219	309
		90		
No base change	63	18	266	347
		81		
Total	134	37	485	656
		171		

Base changes within three years				
Base broadened (+1)	85	24	302	411
Base narrowed (-1)	68	15	242	325
Any base change	104	30	362	496
No base change	30	7	123	160
Total	134	37	485	656

The table provides tabulations of the coincidence of changes to the corporate tax rate and changes to the corporate tax base. A value of +1 indicates a change that has broadened the definition of the corporate tax base, while -1 indicates a change that has narrowed the corporate tax base. The tax rate data are described in Section III. The top panel presents information for each of the 12 corporate tax base measures separately; the bottom panel aggregates over these measures. There are only 656 country-years here, compared to 750 in Tables 2 and 4 because the observations are dropped if we do not have consecutive years of corporate tax rate data. Country-years may have both base-broadeners and base-narrowers, so the number of country-years with any base change is less than the number of country-years with base-broadeners plus the number of country-years with base-narrowers.

Table 6: Linear probability model for tax base changes

	Base broadening	Base narrowing
Rate decrease	0.259***	0.157**
	(0.067)	(0.061)
No rate change	0.198***	0.116**
	(0.060)	(0.052)
Constant	0.300***	0.233***
	(0.087)	(0.080)

The table presents results from linear probability regressions for there being any change to the corporate tax base definition in a particular direction, based on the 12 corporate tax base measures included in our tax base database. All specifications include year fixed effects. Standard errors are clustered at the country level.

Table 7: Replications of key results in previous work

| | Dependent variable: corporate tax revenue/GDP | | | |
	(1) Replication	(2) OLS	(3) Fixed Effects (FE)	(4) First-Difference (FD)
Corp. tax rate	0.271 (0.060)***, [0.022]***	0.274 (0.060)***	0.205 (0.071)***	0.046 (0.035)
Corp. tax rate (sq)	-0.412*** (0.114)***, [0.041]***	-0.401 (0.114)***	-0.181 (0.064)***	-0.027 (0.033)
GDP growth rate	0.047 (0.036), [0.019]**	0.048 (0.036)	0.034 (0.023)	-0.019** (0.007)
Unemp. rate	-0.044 (0.028), [0.012]***	-0.046 (0.028)	-0.038 (0.025)	-0.074 (0.018)***
Log GDP-per-cap.	0.225 (0.260), [0.094]**	0.267 (0.256)	-0.094 (0.670)	0.021 (0.367)
Worldwide	0.412 (0.381), [0.135]***	0.461 (0.389)	-0.158 (0.216)	-0.150 (0.131)
Individual tax - corporate tax	0.012 (0.012), [0.005]**	0.013 (0.012)	0.051 (0.030)*	0.011 (0.016)
Other corp. tax rates		0.592 (0.233)**	0.510 (0.257)*	0.097 (0.171)
Big * tax	-0.065 (0.044), [0.018]***	-0.088 (0.044)*	-0.004 (0.023)	0.014 (0.009)
Big * tax (sq)	0.141 (0.097), [0.044]***	0.205 (0.097)**	0.088 (0.047)*	-0.014 (0.023)
International * tax	0.080 (0.052), [0.022]***	0.076 (0.053)	0.030 (0.026)	0.004 (0.015)
International * tax (sq)	-0.178 (0.117), [0.051]***	-0.169 (0.117)	-0.115 (0.057)*	-0.009 (0.050)
Constant	-4.247 (2.796), [1.075]***	-31.222 (11.297)***	-26.033 (17.718)	
Marginal tax effect	-0.01 (0.02)	-0.001 (0.02)	0.08 (0.04)	0.05 (0.04)
Observations	561	561	561	528
R-squared	0.304	0.318	0.413	0.129

Standard errors in parentheses are clustered by country. In column (1), robust standard errors appear in square brackets. *** p<0.01, ** p<0.05, * p<0.1. Columns (1), (2), and (4) include year fixed effects; column (3) includes differenced year fixed effects. Standard errors for the marginal effect of the corporate tax rate are computed via the Delta Method using standard errors clustered at the country level. The marginal tax effect is evaluated at the average corporate tax rate for the estimation sample.

Table 8: Implied revenue-maximizing tax rates based on replication exercise

	(1) Replication	(2) OLS	(3) Fixed Effects (FE)	(4) First-Difference (FD)
Big=0, International=0	32.91	34.15	56.62	84.74
	(2.55)	(2.91)	(11.70)	(61.46)
Big=1, International=0	38.07	47.27	107.86	73.7
	(5.97)	(10.69)	(64.35)	(44.51)
Big=0, International=1	29.76	30.68	39.69	69.36
	(1.36)	(1.52)	(9.00)	(78.83)
Big=1, International=1	31.88	35.79	55.56	64.55
	(3.87)	(6.06)	(18.70)	(55.92)

Columns (1)–(4) present the implied revenue-maximizing tax rate based on parameter estimates presented in columns (1)–(4) of Table 7. For example, the revenue-maximizing rate for the simple case where $Big = 0$ and $International = 0$, is computed as $-\hat{\beta}_1/2\hat{\beta}_2$, where β_1 and β_2 are the coefficients on the tax rate and tax rate squared terms, respectively. Standard errors for the implied revenue-maximizing tax rate are computed via the Delta Method using standard errors clustered at the country level.

Table 9: Fixed effects regressions with aggregate base measures

	Dependent variable: corporate tax revenue/GDP	
	(1)	(2)
Corp. tax rate	0.206***	0.209***
	(0.072)	(0.074)
Corp. tax rate (sq)	-0.183***	-0.189**
	(0.064)	(0.069)
Cumulative base change	-0.025	-0.077
	(0.018)	(0.166)
Rate * cumulative base		-0.0002
		(0.010)
Rate (sq) * cumulative base		0.006
		(0.016)
GDP growth rate	0.032	0.033
	(0.023)	(0.022)
Unemp. rate	-0.043*	-0.046*
	(0.024)	(0.024)
Log GDP-per-cap.	-0.135	-0.196
	(0.670)	(0.665)
Worldwide	-0.137	-0.079
	(0.196)	(0.183)
Individual tax - corporate tax	0.050*	0.050
	(0.029)	(0.030)
Other corp. tax rates	0.494*	0.498*
	(0.259)	(0.257)
Big * tax	-0.003	-0.001
	(0.022)	(0.025)
Big * tax (sq)	0.085*	0.084*
	(0.044)	(0.049)
International * tax	0.026	0.021
	(0.025)	(0.025)
International * tax (sq)	-0.104*	-0.087
	(0.055)	(0.056)
Constant	-25.044	-24.681
	(17.628)	(17.720)
Marginal effect of τ	0.08	0.09
	(0.01)	(0.01)
Marginal effect of B		-0.07
		(0.17)
Observations	561	561
R-squared	0.415	0.423

Standard errors clustered by country in parentheses. *** p<0.01, ** p<0.05, * p<0.1.Standard errors for the marginal effects are computed via the Delta Method using standard errors clustered at the country level. The marginal tax effect is evaluated at the average corporate tax rate for the estimation sample. The marginal tax rate and tax base effects are evaluated at the mean tax rate and mean cumulative tax base for the estimation sample. All specifications include year fixed effects.

Table 10: Fixed effects regressions with individual base measures

Dependent variable: corporate tax revenue/GDP	
	(1)
Corp. tax rate	0.180**
	(0.072)
Corp. tax rate (sq)	-0.147**
	(0.067)
Other changes to the base	0.014
	(0.073)
Other rate changes	0.103
	(0.081)
CFC legislation	0.136
	(0.170)
Thin capitalization	-0.297
	(0.235)
Loss carry forward	0.065
	(0.167)
Loss carry back	-0.415*
	(0.226)
Accelerated depreciation	0.081
	(0.107)
Investment credit	0.100
	(0.076)
Evasion	-0.108*
	(0.059)
Treatment of foreign companies	-0.166*
	(0.096)
Foreign tax credit	-0.271
	(0.193)
RD tax credit	-0.049
	(0.118)
Big * Tax	0.025
	(0.031)
Big * Tax sq.	0.038
	(0.052)
International * Tax	0.037
	(0.022)
International * Tax sq.	-0.132**
	(0.051)
Constant	-29.641
	(18.854)
Observations	561
R-squared	0.465

Notes: Standard errors clustered by country in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Other variables included in these regressions but not reported are: GDP growth rate, unemployment rate, log GDP-per-capita, Worldwide indicator, personal tax rate less corporate tax rate, average of other countries' corporate tax rates, and year fixed effects.

Table 11: Implied revenue-maximizing tax rates when controlling for the corporate tax base

	(1) Aggregate Base Measure	(2) Aggregate Base Measure + Interactions	(3) Individual Base Measures
Big = 0, International = 0	56.46 (11.33)	55.13 (11.34)	61.31 (14.13)
Big = 1, International = 0	103.80 (57.72)	99.24 (53.16)	94.27 (47.52)
Big = 0, International = 1	40.48 (9.15)	41.62 (9.55)	38.89 (7.60)
Big = 1, International = 1	56.68 (18.86)	59.76 (20.68)	50.24 (12.42)

The table presents the implied revenue-maximizing tax rate from regressions that include measures of the corporate tax base. Columns (1) and (2) correspond to regressions that include a cumulative tax base measure (columns (1) and (2) in Table 9), and column (3) corresponds to a regression that includes individual corporate tax base measures (column (1) in Table 10). Column (2) is evaluated setting the cumulative tax base equal to zero. For example, the revenue-maximizing rate for the simple case where $Big = 0$ and $International = 0$, is computed as $-\hat{\beta}_1/2\hat{\beta}_2$, where β_1 and β_2 are the coefficients on the tax rate and tax rate squared terms, respectively. Standard errors for the implied revenue-maximizing tax rate are computed via the Delta Method using standard errors clustered at the country level.

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A Data Appendix

In this Data Appendix, we provide details of the methodology employed to translate summaries of tax policy changes into indicator variables for types of changes to the corporate income tax base. These indicator variables are derived from summaries of important tax policies published in the International Bureau of Fiscal Documentation's Annual Report publications. For each of the variables, changes that broaden the corporate tax base are coded as +1 while changes that shrink the tax base are coded as -1.

Description of corporate tax base indicator variables

Research and development tax credit

- -1 Research and/or development credit (or deduction) was made available or extended; Additional deduction of research costs was permitted.
- +1 Research and/or development credit (or deduction) was reduced.

Credits for foreign taxes paid

- -1 Foreign tax credit was introduced or increased; the foreign tax credit became easier to obtain; ability to carry forward or back the foreign tax credit was made available or extended; losses could be used to offset foreign source income.
- +1 The scope for the foreign tax credit was reduced or denied; Limitation to the offset of foreign-source losses (Germany 1982).

Tax treatment of foreign companies

-1 Tax exemptions, deductibility of costs, or other investment incentives aimed at attracting foreign investment or multinational headquarter placement; Limited taxation or tax-exempt status of (some) non-resident companies; Liberalization of inward foreign investment; Reduced corporate taxes on companies with a foreign holding; Holdings in foreign corporations granted new exemptions (Germany 1993); Lower tax rates extended to EU companies where previously only applied to resident companies (Greece 2000); Foreign company entry made easier (Korea 1994).

+1 Tax incentives to foreign investors or foreign companies were reduced or withdrawn; Benefits to dual resident companies denied; Certain tax rules extended to non-resident companies; Definition of a resident corporation was expanded; Taxes on income derived from subsidiaries in tax privileged countries was imposed; Limited deduction of expenses of branch offices of non-resident companies; Final withholding on non-resident corporations increased; Deduction for expenses between resident and non-EC companies were disallowed (Italy 1991/2).

Policies that target evasion or avoidance by companies

-1 Increased efforts to combat evasion or avoidance, unless specifically directed at the individual level only, including provisions addressing international profit shifting, provisions to curtail the underground economy and a temporary tax amnesty to encourage the repatriation of capital illegally held abroad.

Investment credits or other tax incentives to promote investment

-1 Investment allowance/premium/deduction was introduced, increased or extended; Exclusion of certain investments from taxation; Tax holiday for investment projects or capital investments; incentives to promote investment; Safe harbor leasing rules for investment credits.

+1 Investment premium or deduction was abolished, reduced or restricted; Companies were no longer allowed to allocate profits to a tax-free investment reserve.

Accelerated depreciation or other depreciation allowances

-1 Increased depreciation rates; Depreciation period shortened; Accelerated write-off of capital expenditures; Threshold for depreciation was increased; Special depreciation allowances granted; Free depreciation scheme introduced.

+1 Use of accelerated depreciation was reduced or abolished; Depreciation rates were reduced; Depreciation period was extended.

Other tax rates that may affect the corporate tax base

-1 Additional tax on business: Exceptional company profits or extraordinary business income (Hungary 1998; Portugal 1987); Excess accumulated income (Korea 1994); Municipal business tax on capital (Luxembourg 1998); Assets tax (Mexico 1995); Special temporary corporation tax (Japan 1994); Branch profits tax (Australia, 1987); Enterprise tax (Japan 1997). Company formation tax: (Hungary

1998). Capital taxes: Property transfer tax (Austria 1987); Transfer of capital (Spain 1980); Income from the increase in invested capital (Italy 1998). Development land tax: (UK 1985). Specific business types: Shipping (Portugal 1991); Foreign technology licensors (Korea 1988).

+1 Additional tax on corporations: Surtax on corporations or surcharge on corporate income tax (France 1995 1997; Germany 1991; Turkey 1995); Large corporation tax on capital (Canada 1989, 1990); Flat tax on tax-reserves of companies (Greece 1998); Special temporary corporation tax (Japan 1991); Special corporate rate on exempt entities (Spain 1987); Branch profits tax (US 1986). Specific business types: Large banks, investment funds or financial institutions (Austria 1981; Denmark 1989; France 1981; Korea 1982); Life insurance companies (Australia 1988; Germany 1993; Sweden 1986); Oil companies or oil windfall profits tax (France 1980, 1981, 2000; Norway 1980; US 1986); Manufacturing profits tax on computer software and data processing firms (Ireland 1984); Telecommunications (Turkey 1999). Capital taxes: Immovable property (Belgium 1994, Germany 1982; Spain 1991); Movable capital (Portugal 1980, 1983). Surcharge on the employment fund: Luxembourg 1991, 1994.

Loss carry-forward

-1 Loss-carry forward was extended or expanded; Limits for carry-forward loss amounts were removed.

+1 Ability to carry forward losses was suspended or restricted.

Loss carry-back

-1 Loss carry-back was introduced.

+1 Ability to carry back losses was restricted.

Thin capitalization rules

+1 Thin capitalization rules were introduced or strengthened (widened); Adjustments were made to thin capitalization rules (assumed to be positive); debt-to-equity ratio was reduced.

Controlled foreign company legislation

-1 CFC legislation was introduced or redefined.

Other changes to the corporate tax base

-1 Eased tax burden of companies generally (Netherlands, 1983) New deduction or exemption permitted: Losses from disposal of fixed assets (Czech Republic 1995); Investment abroad (France 1988); Payroll (France 1998); Cost of issuing new shares (Germany 1984); New employees (Ireland 1982); Bonuses to directors (Portugal 1999); Undistributed profits that are wholly reinvested (Greece 1988); Repatriated earnings (Ireland 1988); Income from overseas services if not taxed in

the source country (Australia, 1980) Corporate income tax incentives in the form of a credit (Hungary 2002) Participation exemption under the corporate income tax was extended (Luxembourg 1988) Level of income below which a proportion tax reduction is allowed was raised (Finland 1984)

+1 Measures to or emphasis on broadening the tax base, without mention of specific provisions (Hungary 1994; Japan 1998; Mexico 1987; US 1982; Turkey 1981) Taxable base for lower rate was increased (Korea 1989) Previous tax incentives restricted or abolished (Poland 1992) Credits reformulated resulting in a sharp decrease in benefits (Spain 1988) Certain provisions replaced, expected to keep total tax burden unchanged (Sweden 1989) Loss of some deduction (Australia 1985; Netherlands 1989); Allowances restricted (Hungary 1991); Expenses were no longer recognized as business-related costs (Hungary 1993); Inventory deduction abolished (Netherlands, 1986) Extension of employment deduction for small and medium business; reduction of certain tax expenditures (Belgium 1984) Certain tax exemptions to promote growth of SME (Belgium 1998) Deductions for corporate entertainment restricted (Japan 1994) Investment deduction for employee profit sharing schemes eliminated (France 1985) Maximum amount allowed to be credited to bad debt reserve were reduced (Japan 1982) Full carry-over of tax benefits from international or contractual agreements (Portugal 1989) Capital allowances phased out (UK 1984); Corporate AMT extended (US 1986)

B   Additional Replication of Previous Work

In this Appendix, we conduct a replication exercise of Devereux (2007), as we did for Clausing (2007) in Section 4.3, using a similar baseline specification. We begin with the simple linear regression given by:

$$R_{it} = \beta_0 + \beta_1 \tau_{it} + \beta_2 \tau_{it}^2 + \Gamma X_{it} + \mu_t + \varepsilon_{it}, \tag{4}$$

where R_{it} is the ratio of corporate tax revenues to GDP, τ_{it} is the top statutory corporate tax rate, X_{it} are control variables, μ_t are year fixed effects, and i denotes country and t denotes year. We use specifications that appear in columns (7) and (9) in Table 1 of Devereux (2007), which correspond to the most generous set of controls. The potential for income shifting is accounted for in two ways: specifications either include the GDP-weighted average of corporate tax rates in other OECD countries or they include the top personal tax rate of the home country. Both sets of regressions include a measure of the corporate tax base, the present discounted value of tax depreciable allowances per dollar of investment in plant and

machinery (PDV of allowances), interacted with all included tax variables.

Table 12 presents results from our replication exercise. Panel A presents results including the GDP-weighted average of other countries' corporate tax rates in the regression as the "alternative" tax rate, and Panel B presents results including the top personal tax rate as the "alternative" tax rate. Standard errors are clustered at the country level. An important difference between these replications and the replications of Clausing (2007) is that these regressions now only include 20 OECD countries, as opposed to 30, due to the availability of data on the PDV of allowances.

Results from estimating these specifications via OLS appear in column (1) of Table 12. The results are qualitatively consistent with Devereux (2007). There is evidence of a non-linear relationship between corporate tax rates and corporate tax revenues, which is highly statistically significant when controlling for the personal tax rate.[31] The estimated revenue-maximizing corporate tax rate evaluated at the mean of the PDV of allowances for the estimation sample (0.773) is 32%. As found in the original study, the "alternative" tax rate variable plays a significant role in neither specification.

Next, we account for unobserved time-invariant heterogeneity by including country-specific fixed effects (FE) and by estimating equation in first-differences (FD). Results from the FE and FD specifications are presented in columns (2) and (3) of Table 12, respectively. In all of these specifications, the relationship between corporate tax rates and corporate tax revenues becomes attenuated, and none of the corporate tax rate variables are statistically significant at the 5% level. Some of these specifications oddly imply a convex relationship between corporate tax rates and corporate tax revenues. The implied revenue-maximizing rates from these specifications cover a surprisingly large range, from -18% to over 100%. These results are consistent with the explanation put forth in both Clausing (2007) and Devereux (2007) for not controlling for time-invariant unobserved heterogeneity: that insufficient within-country variation remains to identify corporate tax rate effects.

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[31] The p-value on the level of corporate tax rates in column (1) is 0.12.

Table 12: Replications of Devereux (2006)

Dependent variable: corporate tax revenues/GDP			
	OLS	FE	FD

Panel A: Including GDP-weighted average of other countries' corporate tax rates

	OLS	FE	FD
Corp. tax rate	1.110	0.683	-0.003
	(0.677)	(0.697)	(0.203)
Corp. tax rate (sq)	-1.879*	-0.657	0.157
	(0.979)	(0.795)	(0.200)
Other corp. tax rates	-0.226	-0.482	-0.125
	(0.455)	(0.472)	(0.123)
Depreciation x tax	-1.122	-0.840	0.009
	(0.851)	(0.870)	(0.272)
Depreciation x tax (sq)	1.933	0.808	-0.187
	(1.183)	(0.969)	(0.271)
Depreciation x other tax rates	0.220	0.482	0.076
	(0.376)	(0.452)	(0.164)
Constant	1.412	5.986	
	(14.427)	(14.356)	
Observations	456	456	437
R-squared	0.314	0.284	0.121

Panel B: Including top personal tax rate

	OLS	FE	FD
Corp. tax rate	1.071**	-0.238	-0.509
	(0.482)	(0.285)	(0.318)
Corp. tax rate (sq)	-1.640**	0.142	0.632*
	(0.653)	(0.475)	(0.323)
Personal tax rate	-0.176	0.223***	0.202
	(0.178)	(0.068)	(0.143)
Depreciation x tax	-1.078*	0.337	0.643
	(0.551)	(0.282)	(0.375)
Depreciation x tax (sq)	1.639**	-0.194	-0.782*
	(0.738)	(0.476)	(0.373)
Depreciation x pers. tax rate	0.230	-0.226**	-0.248
	(0.218)	(0.096)	(0.170)
Constant	-1.406**	-1.536	
	(0.532)	(2.832)	
Observations	453	453	434
R-squared	0.324	0.359	0.147

Notes: Standard errors in parentheses are clustered by country; robust standard errors appear in bracket. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Columns (1), (2), and (4) include year fixed effects and a constant; columns (3) and (5) include differenced year fixed effects. The implied revenue-maximizing tax rate is computed as $-(\hat{\beta}_1 + \hat{\beta}_D)/2\hat{\beta}_2$, where β_1, β_2 and β_D are the coefficients on the corporate tax rates, the corporate tax rate squared, and the interaction of the PDV of allowances and the corporate tax rate, respectively. This revenue-maximizing rate is evaluated at the average PDV of allowances for the estimation sample.