# Taxes and the Global Allocation of Capital[*]

David Backus,[†] Espen Henriksen,[‡] and Kjetil Storesletten[§]

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## Abstract

Despite enormous growth in international capital flows, capital-output ratios continue to exhibit substantial heterogeneity across countries. We explore the possibility that taxes, particularly corporate taxes, are a significant source of this heterogeneity. The evidence is mixed. Tax rates computed from tax revenue are inversely correlated with capital-output ratios, as we might expect. However, effective tax rates constructed from official tax rates show little relation to capital — or to revenue-based tax measures. The stark difference between these two tax measures remains an open issue.

**JEL Classification Codes:** E22, F21, H25, H32.

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# 1 Introduction

With net flows of financial capital into the US running at about 7% of GDP — and similar flows out of Germany and Japan — it's increasingly difficult to think about the allocation of physical capital without considering its international dimension. We may not live in a world of frictionless international capital markets, but international markets nevertheless appear to have a significant impact on local conditions. Despite this, there are substantial differences in the capital intensities of developed countries. By our calculations, capital-output ratios in 2004 were about 2.5 in the US, 3.1 in France, 3.9 in Japan, and 1.8 in Ireland. These differences in capital-output ratios suggest similar differences in marginal products. If the US and Japan produced output with the same Cobb-Douglas production function, with a capital share of one-third, the implied marginal product of capital would be about 5% higher in the US. The question is why. While some ask why capital flows out of Japan and into the US are so large, we ask why they aren't large enough to eliminate a conjectured 5% rate of return differential.

There are many possible sources of cross-country differences in capital-output ratios, but we focus on one: taxes, particularly corporate taxes. Could differences in tax rates account for some of the heterogeneity we see in capital-output ratios? Certainly corporate tax rates differ substantially across countries, and these differences can, in principle, generate substantial variation in capital-output ratios. The US, for example, now has a relatively high corporate tax rate, which might offset the advantages to an investor of its apparent high marginal product of capital.

We examine data on capital and taxes in a panel of OECD countries over the last 25 years to see whether the two variables are related in a statistical sense. The answer? It depends how you measure tax rates. For that reason, much of our effort is devoted to measurement issues.

We proceed as follows. In Section 2, we describe the relation between the capital-output ratio and the tax rate on capital in a frictionless theoretical example. The example provides a concrete illustration of how high taxes on capital might be asso-

ciated with low capital-output ratios. In Section 3, we look at capital data, summarizing the behavior of capital-output ratios across countries and over time. Although capital-output ratios have been stable in most countries, the data exhibit substantial variation both over time and across countries. Measurement issues include investment price deflators and depreciation schedules. In Section 4, we look at tax data. We use two sources: revenue collected by various taxes, including taxes on corporate income, and effective tax rates constructed from features of the tax code. Tax systems are enormously complex, so each of these approaches raises substantive measurement issues. With effective tax rates, we show that there's been a dramatic convergence over the last decade or so, as well as a decline in average tax rates. Tax revenue, however, has changed much less as a fraction of GDP. The difference between these two measures is a central issue in interpreting the evidence. Have corporate tax rates become more similar across countries — or not? In Section 5, we look at the relation between capital-output ratios and tax rates. For measures of tax rates based on corporate tax law, the correlation with the capital-output ratio is small or positive. However, for measures based on tax revenue the correlation is clearly negative, with countries that collect more tax revenue having, on average, less capital per unit of output. However, even revenue-based taxes explain only a small fraction of the observed variance in capital-output ratios. A more formal analysis based on panel regressions leads to similar conclusions. In the final two sections, we explore a range of related issues, including mechanisms that might lead to correlations between capital and taxes for reasons other than the direct impact of tax rates on investment decisions.

We are left with two outstanding issues: why effective and revenue-based tax rates are so different, and why even revenue-based measures explain such a small fraction of international differences in capital-output ratios.

## 2 The allocation of capital in theory

An example shows how international capital mobility might interact with taxes in producing an allocation of capital across countries. The idea is that taxes on capital

reduce its use, leading countries with high taxes (suitably defined) to use less capital than those with low taxes. We emphasize taxes levied on businesses for reasons that should become apparent later on.

Consider a world with one good and many countries across which physical capital can be shifted costlessly. In each country $i$, a representative firm produces output $y_{it}$ at date $t$ using capital $k_{it}$ and labor $n_{it}$ according to the same production function $f$:

$$y_{it} = f(k_{it}, z_{it}n_{it}),$$

where $f$ is homogeneous of degree one and $z_{it}$ is exogenous labor-augmenting productivity. Firms purchase capital $k_{it}$ in the previous period at price $p_{t-1}$, the same across countries. Capital and labor generate output $y_{it}$ and next-period capital $(1-\delta)k_{it}$, where $\delta$ is the depreciation rate. This "gross output" has price $p_t$. The price of labor in country $i$ is $p_t w_{it}$ per unit, so that $w_{it}$ is the wage in units of the date-$t$ good. The interest rate is $1 + r_{t-1} = p_{t-1}/p_t$.

Without taxes, the profit of a competitive firm in country $i$ is

$$\text{Profit} = p_t[f(k_{it}, z_{it}n_{it}) + (1-\delta)k_{it} - w_{it}n_{it}] - p_{t-1}k_{it}.$$

Its optimal choice of capital follows from the first-order condition:

$$1 + r_{t-1} = 1 + f_k(k_{it}, z_{it}n_{it}) - \delta, \tag{1}$$

where $f_k(k, zn) = \partial f(k, zn)/\partial k$ is the marginal product of capital gross of depreciation. Since firms in all countries have the same technologies and face the same interest rate, they equalize their marginal products of capital. We can be more specific if we have a CES production function,

$$f(k, zn) = [\omega k^{\nu} + (1-\omega)(zn)^{\nu}]^{1/\nu},$$

with $0 < \omega < 1$ and $\nu \leq 1$. The elasticity of substitution between the two inputs is $\sigma = 1/(1-\nu)$. Then the marginal product of capital is related to the capital-output ratio by

$$f_k(k_{it}, z_{it}n_{it}) = \omega(k_{it}/y_{it})^{\nu-1}, \tag{2}$$

so that international capital markets equate capital-output ratios.

With taxes, the international allocation of capital depends on tax rates and the way in which taxes are collected. The most common version is to tax returns to capital net of depreciation at a constant rate $\tau_{it}$, so that after-tax profit is

$$\text{Profit} \;\; = \;\; p_t \left[ (1 - \tau_{it})\{ f(k_{it}, z_{it}n_{it}) - \delta k_{it} - w_{it}n_{it} \} + k_{it} \right] - p_{t-1}k_{it}.$$

In an international context, the implicit assumption is that capital taxes are source-based: the tax rate applies to the country in which the capital is used, regardless of who owns it. The first-order condition for capital now implies

$$1 + r_{t-1} \;\; = \;\; 1 + (1 - \tau_{it}) \left[ f_k(k_{it}, z_{it}n_{it}) - \delta \right]. \tag{3}$$

In the CES case, there is an inverse relation across countries between the tax rate on capital and the capital-output ratio. This relation is predicated on countries having identical production functions. Differences in, say, depreciation rates $\delta$ or share parameters $\omega$ also lead to international differences in capital-output ratios.

A numerical example gives us a sense of the magnitudes involved. Suppose $\nu = 0$ (Cobb-Douglas production function), $\omega = 1/3$ (capital's share), and $\delta = 0.08$ (depreciation rate). Then the marginal product of capital is 13.3% with the US capital-output ratio of 2.5, 10.8% with France's ratio of 3.1, and 8.5% with Japan's ratio of 3.9. Now consider the impact of taxes. Suppose the US tax rate is 25%, a number we use purely for illustration. Then the after-tax (net) return is 4.0%. If the tax is eliminated, the capital-output ratio that generates the same after-tax return is 2.78, a significant increase over 2.5. More generally, the magnitude of the impact will depend on the elasticity of substitution, which is one in this case.

Real-world taxes raise a number of issues that go beyond our example, including our focus on business taxes. Among them are

- Personal taxation. Most governments tax capital income received by individuals, including interest receipts, dividends, rent, and capital gains. Tax-sheltered pensions and personal saving mitigate the impact of personal taxes on capital

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income in most countries, but the degree of mitigation is an open issue. Owner-occupied housing goes the other way, with many countries subsidizing it relative to other housing. In practice, it's difficult to measure the effective personal tax rate on capital income alone, since personal income tax systems typically lump capital and labor income together. Moreover, taxation at the personal level is more likely to be based on the location of the investor (residence-based) than the investment (source-based).

Personal taxes also raise issues about the integration of personal and business taxes. In the US, for example, dividends are taxed at both the corporate and individual levels, while interest payments are not. In contrast, many other countries credit individuals with any taxes paid by corporations on dividends.

- Heterogeneous treatment of producers. We focus on international differences in tax rates, but there are also important differences across producers in the same country. One such difference is legal structure: corporations, privately-held firms, partnerships, and nonprofits are taxed at different rates in many countries. In the US, the income of traditional "C" corporations is taxed directly, but the income of "S" corporations (typically smaller firms with fewer shareholders) is treated as individual income but not taxed at the corporate level. Some tax rates depend on the industry of the producer. And differences in the technology of production (capital intensity and depreciation, for example) or in the method of financing (debt, equity, or retained earnings) can lead to different effective tax rates even when the statutory rates are the same.

- Taxation of multinational corporations. Producers who operate in more than one country face multiple tax authorities as a result. There are no general rules about how these tax systems interact; where multinational tax agreements exist, they often differ across pairs of countries. In the worst case, the overall tax rate can be higher than the highest individual rate. But firms typically have numerous opportunities to shift revenue and expenses across countries: transfer pricing, issuing debt in high-tax countries, collecting royalties in low-tax countries, and so on, which can reduce overall effective tax rates substantially.

It's hard to say where this leaves incentives to invest in physical capital.

These issues and more are discussed at length by Auerbach (2006), Congressional Budget Office (2005), Devereux (2006), Devereux, Griffith, and Klemm (2002), Jorgenson (1993), King and Fullerton (1984), McGrattan and Prescott (2005), Mintz (1995), and Poterba and Summers (1985). Most of these papers include extensive references to the relevant literature. Our first-order approximation is Auerbach (1979) and King (1974): firms finance investment with retained earnings at the margin and corporate taxation alone affects investment decisions.

# 3   The allocation of capital in practice

After Feldstein and Horioka (1980) wrote their celebrated paper on international capital mobility, economists realized that net capital flows had played little role in the allocation of capital across developed countries in the 1960s. Countries with high saving rates also had high investment rates. Equally striking but less celebrated were the large differences in those rates: average investment rates ranged from 19% in the UK and the US to 26% in France and an astounding 37% in Japan. (These numbers are averages for 1960-74, reported in their Table 1.) Even with differences in output growth rates and the prices and composition of investment goods, this range of investment rates must surely reflect substantial differences in capital-output ratios.

Since then we have witnessed a dramatic increase in the scale and scope of international financial transactions, and even some weakening of the link between saving and investment. Has there been a parallel tendency toward convergence of capital-output ratios across countries? Figure 1 and Table 1 suggest not. It's apparent in both that capital-output ratios continue to vary across countries, and in some cases across time as well.

In Figure 1, we describe capital-output ratios for OECD countries for the period 1980 to 2004. The top panel summarizes the cross-country evidence with "spaghetti plots:" a time series plot of 15 countries over the whole period. The countries (here

and throughout the paper) are Australia, Austria, Belgium, Canada, Finland, France, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland, the UK, and the US. Individual countries are not identifiable in the figure, but the plot gives us a sense of both dispersion across countries and changes over time. The bottom panel tells the same story with time series of cross-section means and standard deviations. Over this period the mean fell and the standard deviation rose, but both changes have been small. We find the lack of convergence somewhat surprising, given the globalization of capital markets over the last 25 years, but it's a robust feature of the data.

We find the behavior of individual countries equally interesting, if not necessarily representative. In the US, the capital-output ratio has been between 2.4 and 2.8 since 1970. In France, the capital-output ratio rose from 2.6 to 3.1 during the 1970s, but has been between 3.0 and 3.2 ever since 1980. In Japan, by contrast, the capital-output ratio has risen steadily, from 2 in 1970 to 3 in 1980 to almost 4 in 2005[??]. The investment rate fell in the 1990s, but slower growth in output led to further increase in the ratio of capital to output. In Ireland, the capital-output ratio fell from 3.0 in 1986 to about 1.8 in 2005, a period of rapid growth and (apparently) low corporate tax rates. The standard deviations bottom panel of the figure remind us that increase in dispersion suggested by Ireland and Japan is not representative, but they are interesting examples in their own right.

In Table 1, we report the same data in different form. There we see, for example, that the variation in total capital-output ratios in our panel is substantial: the overall standard deviation is 0.45, about 15% of the mean of 3.1. The standard deviation between countries (the standard deviation of the country means) is almost as large (0.41), suggesting that most of the variation in our panel is between countries. The components of capital are similar: government, housing, and business capital all show considerable variation, with difference between countries accounting for most of it.

The capital stocks on which these tables and figures are based are computed from real investment series in the OECD's *Economic Outlook Database*. The database includes three categories of investment: government, private housing, and other private investment (business plant and equipment). We construct stock series for each

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component by the perpetual inventory method using depreciation rates specific to each category starting with values for 1970 (our starting point) reported by Kamps (2006). Sources and methods are described further in Appendix A. Extensive experimentation with differences in depreciation schedules suggests to us that none of the specifics matter much as long as countries are treated the same way.

This approach to capital measurement is the industry standard, but there are nevertheless some issues to consider. One is that the composition of business capital has changed over time, and may differ across countries as well. In the US, there's been a shift in business investment from structures to equipment and software, with the result that the average depreciation rate has risen. See, for example, the discussion in Gomme and Rupert (2007). The OECD data do not have enough detail to allow us to account explicitly for differences in composition; we try to account for this by using depreciation rates for business and government capital that increase over time. A related issue is that the definition of capital goods differs somewhat across countries, with the US including software and most other countries not. Intangibles, such as patents, brand equity, and databases, are disregarded uniformly. There is little we can do about either with existing data. A third issue is that real investment is based on official price indexes, whose quality varies across countries. In the US, price indexes incorporate large adjustments for quality improvements, which raises measures of real investment. Some observers think this is done less successfully in other countries, so that their real investment series are understated.

All of these issues are worth mentioning, but we nevertheless think there is more signal than noise in observed capital-output ratios. Countries with high capital-output ratios are generally those with high investment rates, so it would take an amazing congruence of measurement errors to eliminate or reverse the ranking of capital intensities across countries.

# 4 Taxes in practice

The next step is to examine data on tax rates. Taxes have virtually unlimited potential for complexity, but our hope is that reasonable summary measures will capture some of the tax incentives to purchase and use physical capital. We focus on corporate tax rates for reasons outlined in Section 2.

There are two common approaches to measuring tax rates, on capital and otherwise. One is based on official tax rates, the other on tax revenue. We look at both. So-called effective corporate tax rates are based on official rates. The current state-of-the-art for corporate taxation starts with King and Fullerton (1984), who summarized the many features of existing tax systems in a one-dimensional measure. Effective tax rates take statutory rates and make adjustments that bring them closer to the rates relevant for investment decisions. One is accelerated depreciation. Many countries allow companies to subtract depreciation at a faster rate, which reduces the tax burden on capital by bringing the depreciation allowance forward in time. Some countries even allow investments to be "expensed," making depreciation effectively immediate for tax purposes and possibly eliminating the incentive effects of the tax (Abel, 2007). Another adjustment is tax credits: tax reductions or even subsidies for some kinds of investment. A third is debt. Most countries allow companies to subtract interest on debt from taxable income, which reduces the effective tax rate on investments financed by debt. The impact of this change depends on the nominal interest rate, hence inflation.

We use Devereux, Griffith, and Klemmm's (2002) implementation of this methodology. We take three of their measures: the statutory corporate tax rate, the marginal effective rate, and the average effective rate. All of these tax rates vary, in principle, across industries and regions within countries, so the reported rates require some judgement about what a typical company would pay. In Table 1, we see that rates of all kinds differ substantially across countries. The statutory corporate tax rate in our sample has a mean of 38% and a standard deviation of 11%. The standard deviation of country means is 8%, so about half the total variance is between countries. Effec-

tive marginal and average rates are lower, on average, but exhibit similar variation. Again, much of the variation is between countries, although not to the extent we saw with capital-output ratios.

Figure 2 shows, however, that there has also been significant variation over time in the effective marginal tax rate. In the top panel, we see both a decline in the overall level of tax rates and a decline in dispersion. Both show up in the bottom panel, where we see that the mean tax rate has fallen from about 30% to below 20%. The cross-section standard deviation has declined by two-thirds over the same period. Both of these features are documented by Devereux, Griffith, and Klemmm (2002). Statutory and effective average tax rates (not shown) have similar properties.

The second approach to measuring tax rates is to base them on tax revenues. If we have information on tax revenues and the tax base, then we can compute a tax rate as the ratio. Mendoza, Razin, and Tesar (1994) is the template, and Carey and Rabesona (2002) is a recent extension and refinement. In the case of capital taxation, taxes are paid by individuals through the personal income tax and businesses through corporate or other business taxes. In some cases, there are direct levies on capital that should also be included: property taxes, wealth taxes, and so on. The idea behind this approach is that by looking at taxes paid we get a realistic picture of the tax burden. There are also some well-known problems. One is that we have, by construction, a backward measure of the average tax rate, not the marginal rate applied to current investments. Another is that it's often difficult to find reliable data on the relevant tax base. For example, in the case of personal taxation of capital income, it's not clear from standard data sources how much of the revenue from the personal income tax comes from taxes on capital income rather than labor income. Similarly, for corporate taxes it's difficult to find measures of taxable corporate income that correspond to reported tax revenue. Finally, revenue-based tax measures typically make no distinction between average and marginal tax rates.

We construct several revenue-based tax measures from data collected by the OECD and reported in its *Revenue Statistics of OECD Member Countries*. Personal taxes are reflected in revenue collected from individual income taxes expressed

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as a fraction of GDP. Tax rates are likely higher than this, since the tax base is smaller than GDP, but it's not clear how to approximate the relevant tax base. Table 1 shows that the average has been 11% with a standard deviation of 3%. Corporate taxes are reflected in revenue from corporate income taxes. We express this revenue as a ratio to GDP and as a ratio to a crude approximation to gross capital income, which we describe next.

We approximate gross capital income, capital's share of GDP, and the average product of capital with income data from the OECD's *Annual National Accounts*. The central difficulty is that these accounts do not contain detailed breakdowns of gross domestic income that translate directly into labor and capital income. The category "gross operating surplus and mixed income" includes, among other things, corporate income (presumably capital) and mixed income (what US accounts refer to as "proprietors' income," a combination of labor and capital income). We divide this into its components — operating surplus and mixed income – using average shares in the US: 35% operating surplus and 65% mixed income. Next we divide mixed income between labor and capital using the same shares as other income. Finally, we disregard taxes and subsidies in both factor income and total income, computing factor shares from what's left. The factor shares are then applied to gross domestic income to produce factor incomes. This calculation leads to the measures summarized in Table 1. Capital's share is 34%, on average, with standard deviations of 4% overall and 3% between countries. The average product of capital, measured as a ratio of capital's share to the capital-output ratio, is 11%, with a standard deviation of 2% both overall and across countries.

The striking feature of our two revenue-based tax measures — ratios of corporate tax revenue to GDP and gross capital income — is how different they are from the effective rates. The revenue-based tax rate (the ratio of corporate tax revenue to capital income) is much smaller, perhaps because the tax base is too large: it includes depreciation and the income of noncorporate business, neither of which is part of the corporate tax base. This level effect does not explain, however, the large difference in time series behavior. While the effective rates have fallen and converged over the last 25 years, Figure 3 shows that the revenue-based tax rate has increased, on average,

with little change in the dispersion across countries. Devereux (2006) documents a similar discrepancy between effective tax rates and corporate tax revenue expressed as a fraction of GDP.

In short, tax rates based on the tax code and tax revenues give much different pictures of recent history.

# 5   Capital and taxes in practice

We've now seen international evidence on capital, in the form of capital-output ratios, and taxes, in the form of effective tax rates on corporate income and revenue-based measures of personal and corporate income taxes. Both exhibit substantial variation across countries. We can now address our question: are cross-country differences in capital intensity related to differences in tax rates? Certainly theory suggests that an increase in tax rates will reduce the amount of capital used in production. Is that what we see in the data? We look at the data in two ways: with bivariate correlations and panel regressions.

## Correlations

In Table 2, we report correlations between pairs of the same variables we described in Table 1: capital-output ratios, tax measures, and some other variables. The essence of our findings is apparent in the correlations between capital-out ratios and taxes.

For effective tax rates, the correlations are consistently positive: countries with high tax rates also have high capital-output ratios on average. For example, the correlation of the effective marginal corporate tax rate with the total capital-output ratio is 0.41. If high tax rates discourage capital formation, there is little evidence of it in this data. The positive correlation between tax rates and capital intensity is puzzling, especially given the amount of variation in each. One possibility is that our definition of the capital stock (total capital) is too broad: certainly government capital, and perhaps housing, are not subject to the same tax incentives facing business capital.

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Yet when we look at business capital alone, the result is the same: capital and tax rates are positively correlated.

The positive correlation between capital and taxes reflects both time series and cross section dimensions of the data, but we'll see shortly that the cross section is central. France, for example, has a high capital-output ratio, but also a high tax rate. Even in the time series, there is little evidence of a negative relationship. We've seen that corporate tax rates have declined, on average. We might therefore expect to see an increase in capital-output ratios. We don't. Average capital-output ratios have been flat. Ireland, for example, has the lowest tax rates in our sample, but in recent times has also had a low capital-output ratio. Ireland also experienced a sharp drop in corporate tax rates, yet its capital-output ratio has fallen. Moreover, a substantial drop in France's corporate tax rate has been associated with virtually no change in its capital-output ratio. This pattern holds whether we look at statutory corporate tax rates or any of the effective tax rates computed by Devereux, Griffith, and Klemm (2002). It seems that the state-of-the-art in modern public finance is of little help in explaining differences in the global allocation of capital.

In contrast, revenue-based tax rates are negatively correlated with capital intensity. For example, the correlation of corporate tax revenue, expressed as a ratio to capital income, with the total capital-output ratio is –0.37. Note, too, that the revenue-based tax rate is negatively correlated with the effective tax rate.

Evidently it makes a big difference which tax measure we use, but many of the details matter less. Note, first, that the three "official" corporate tax rate series are highly correlated: the statutory tax rate, the effective marginal tax rate, and the effective average tax rate. The three are based on similar inputs, and lead to similar measures of tax rates as a result. Second, the correlations of these tax rates with revenue-based measures are small or even negative. For example, the correlation between the effective marginal tax rate and the ratio of corporate tax revenue to GDP is 0.16. The two measures are clearly picking up different things. Third, the capital series are highly correlated, especially total capital and business capital. For this reason, it makes little difference whether we look at total capital, business capital, or

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private capital (business plus housing). Finally, capital-output ratios are positively correlated with our three measures of corporate tax rates, but negatively with corporate tax revenue. This last finding is directly related to the role of taxes in the global allocation of capital, and therefore worth a closer look.

## Regressions

The correlations between capital and tax measures are suggestive, but panel data regressions shed additional light on both the source of the correlation (time series or cross section?) and its magnitude (are the numbers reasonable given our theory?). Put more concretely: These regressions allow us to vary the source of information by using time and country fixed effects. They also allow us to interpret the coefficients as the elasticity of substitution between capital and labor, allowing us to judge whether the magnitude is reasonable.

We estimate a relation between capital-output ratios and tax rates that follows from our theoretical example. If we allow countries to have different production functions, then equations (2) and (3) imply

$$(1 - \tau_{it}) \left[ \omega_i \left( k_{it}/y_{it} \right)^{\nu-1} - \delta \right] \;\;=\;\; (1 - \tau_{jt}) \left[ \omega_j \left( k_{jt}/y_{jt} \right)^{\nu-1} - \delta \right] \;\;=\;\; r_{t-1},$$

where $\omega_i$ is a country-specific capital share. We refer to $(1 - \tau)$ as the "tax wedge." If $\delta \left( \tau_{jt} - \tau_{it} \right)$ is small, then

$$\Delta \log \left( k_{it}/y_{it} \right) \;\;\approx\;\; \sigma \, \Delta \log \left( 1 - \tau_{it} \right) + \sigma \, \Delta \log \omega_i, \tag{4}$$

where the notation $\Delta x_j$ refers to the difference in variable $x$ for country $j$ relative to the US (so that $\Delta x_j \equiv x_j - x_{US}$). This differencing is equivalent to using fixed effects for time, eliminating (in our example) the impact of variation in the world interest rate. As before, $\sigma = 1/\left( 1 - \nu \right)$ is the elasticity of substitution between capital and labor. Country-specific share parameters $\omega_i$ lead to country fixed effects.

One implication of equation (4) is that the variation in tax rates is too small to account for the variation we see in capital-output ratios. Suppose, for example, that

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$\sigma = 1$ (the Cobb-Douglas case) and all countries have the same capital share $\omega$. Then the log-difference in capital-output ratios must equal the log-difference in tax wedges. The variances are related in general by

$$Var\left[\Delta \log\left(k_j/y_j\right)\right] \quad = \quad \sigma^2 \, Var\left[\Delta \log\left(1 - \tau_j\right)\right].$$

In our data, the cross-country variance of the left-hand side 0.03. The cross-country variance of the right-hand side is about 0.01 for effective tax rates, and much less for revenue-based tax rates. With a plausible elasticity of substitution, it's clear that these tax rates do not vary enough across countries to account for a large share of the variance of capital-output ratios in our data.

We report estimates of equation (4) with a variety of tax measures in Table 3. The dependent variable in each case is the log-difference in (total) capital-output ratios. The message is similar to what we found with correlations. With effective tax rates, the impact of taxes on the capital-output ratio depends on whether we include country effects. Without them [regression (B)], the coefficient estimate is –0.34. With them [regression (C)], the estimate is 0.14. It appears, then, that it's the cross-section information that drives the estimate to be negative: when we introduce country fixed effects, the sign changes. Even in this case the magnitude is small, particularly if we interpret it as an elasticity of substitution. With our revenue-based tax rate, the coefficient estimate is positive both with and without country effects [regressions (H) and (I), respectively]. Moreover, the magnitudes (1.38 and 1.04) are consistent with something like a Cobb-Douglas production function.

The broad features of this evidence survive when we confront them with a battery of sensitivity tests (not reported). They include:

- *Private capital.* Our theory has implications for *private* capital decisions, yet we reported regressions using total capital. If we use the ratio of business capital to GDP, or of private capital (business plus housing) to GDP, very little changes. We might also use the ratio of business private capital to the comparable measure of output, but that poses a challenge of measurement challenge: we do not have direct measurements of private GDP. We therefore approximate

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it by subtracting government purchases. With this approximate measure, the estimated coefficients are often larger, but the stark difference between effective and revenue-based tax rates remains.

- *Stability over time.* Some have argued that capital mobility, which underlies our theory, is a better approximation in the second half of our sample than the first. If we split the sample in two — 1980-1992 and 1993-2005 — the coefficients are more precisely estimated in the second half of the sample. If we include country fixed effects, the coefficient of the effective marginal tax rate in the second half of the sample remains small and the coefficient of the revenue-based tax rate rises. The changes are small in both cases, but the latter might suggest that there has been an increase in the degree of capital mobility over our sample period.

- *Business cycles.* Another modification is to eliminate the high-frequency or business cycle variation in the data, possibly because we think taxes operate over longer periods of time. If we use five-year averages of the variables in our regressions, the changes in coefficient estimates are modest but the standard errors increase substantially.

No doubt others will think of more ways to interpret the data, but it seems to us that the features we've described are reasonably robust to a broad range of variation in statistical methodology.

The bottom line? Both correlations and regressions show significant relations between capital-output ratios and corporate tax rates. The difficulty is that the sign of the relation depends on how we measure tax rates. With effective tax rates, then higher taxes are associated with higher capital-output ratios. But with revenue-based tax rates, higher taxes are associated with lower capital-output ratios. The latter are easier to rationalize, but both are resilient features of our data.

# 6 Discussion

The data give us two different messages: effective tax rates are positively correlated with capital-output ratios, while revenue-based tax rates are negatively correlated. A reasonable person could emphasize either one, or perhaps neither. We lean toward the evidence from revenue-based taxes (high tax rates discourage capital formation), but it's worth further discussion.

*Measurement error.* None of our data are measured without error: capital-output ratios, tax rates, and so on. Could measurement error account for some or all of what we've found? Classical measurement error of capital would tend to reduce its correlation with all variables, which hardly explains why our two tax measures have correlations of opposite sign. However, we can imagine more complicated arguments in which the same measurement error has the opposite effect on capital and tax rates. One such example is measurement error in income/output, which might (so the story goes) increase income tax revenues and decrease capital-output ratios, thereby generating a negative correlation between the two. There is, in fact, a tendency for tax revenues to rise in booms, perhaps through a distribution effect on firms: the percentage of loss-making firms falls, raising measured average tax rates. It's not clear whether this effect is large enough to generate the correlation we see in the data, but it's a possibility.

*Reverse causality.* Another possibility is that the correlations we've documented are right, but are delivered by a different mechanism. Here's one such story. Suppose capital owners lobby to influence the taxes they pay. Then they would likely lobby more when the capital-output ratio is high, possibly generating lower taxes in such cases. This produces the negative correlation between capital and tax rates we described earlier, but the causality works the other way: high capital intensity leads to lower tax rates. Alternatively, we might imagine that the political process balances the adverse incentive effects of capital taxation against their ability to raise revenue. The latter is likely to be more important when capital intensity is high, which could generate a positive association between capital tax rates and capital-output ratios.

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Hassler, Krusell, Storesletten, and Zilibotti (2004) provide an illustration of this mechanism. Both show that the relation between capital and taxes can be more complex than the example we described in Section 2.

*Micro and macro evidence.* In the investment literature, studies generally find little impact of taxes with aggregate data, but substantial impact when they use firm or industry data. See, for example, Hassett and Hubbard's (2002) survey. Gordon and Hines (2002) and and Hines (1999) describe a similar difference between macro and micro evidence in the international tax literature. From this perspective, our suggestion of a significant impact of taxes in aggregate data is unusual. Whether it represents an improvement in measurement or something entirely different remains to be seen.

# 7    Final thoughts

We've examined the role of taxes, particularly corporate taxes, on the global allocation of physical capital in a sample of OECD countries between 1980 and 2004. The results are mixed. If we take the state-of-the-art in public finance — various measures of effective corporate tax rates — there's little relation between capital and taxes. If we take corporate tax revenue as an indicator of tax rates, the results are stronger: countries that collect a lot of tax revenue also have less capital, on average. Even these results raise some questions. One question is why differences across countries are so large. Even the most optimistic interpretation of the evidence leaves a large fraction of the variation in capital-output ratios unexplained. Another is why the two measures of tax variables are so different.

In some ways, our difficulty in disentangling the impact of taxes from other factors reflects a similar difficulty that public finance economists have had with firm-level data. Despite overwhelming anecdotal evidence that taxes affect firm decisions, it's taken both effort and imagination to detect this impact in the data. Devereux (2006), Gordon and Hines (2002), and Hines (1999) list numerous examples that show that we're not alone in this respect. Like them, we are left with some suggestion that the

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evidence may support our premise, but also with the feeling that the factors that affect investment decisions go well beyond taxes.

# A  Data sources

Tables and figures are based on data from the following sources:

- *Devereux-Griffith-Klemm Corporate Tax Rate Data.* This is an updated version of the data used in Devereux, Griffith, Klemm (2002). We use the statutory tax rate (sheet A1), the effective marginal tax rate (sheet A8), and the effective average tax rate (sheet A12).

- OECD, Tax Revenue Database: *Revenue Statistics of OECD Member Countries*. This includes government tax revenue by category of tax. We use two components of "taxes on income, profits, and capital gains": taxes on individuals (1100) and taxes on corporations (1200). We also use "taxes on property" (4000).

- OECD, *Economic Outlook Database.* We use GDP and its expenditure components. Real investment data are used to construct capital stocks by the perpetual inventory method. We decompose real investment into housing, government, and business components and apply different depreciation rates to each. The depreciation rate for private residential capital is constant and equal to 1.5%. The depreciation rate for government capital increases linearly from 3% in 1970 to 4.15% in 2004. The depreciation rate for business capital increases linearly from 5.25% in 1970 to 8.50% in 2004.

- OECD, *Annual National Accounts.* This is our source for the components of gross domestic income that we use to approximate capital income.

The OECD data are available through SourceOECD.org. The Devereux-Griffith-Klemm data are from the website of the Institute for Fiscal Studies.

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Table 1: Capital and taxes: summary statistics

| Variable | Mean | Standard Deviation | |
| --- | --- | --- | --- |
| | | Overall | Betw. Countries |
| *Capital* | | | |
| Total capital (ratio to GDP) | 3.11 | 0.45 | 0.41 |
| Government capital (ratio to GDP) | 0.56 | 0.19 | 0.19 |
| Housing capital (ratio to GDP) | 1.30 | 0.25 | 0.25 |
| Business capital (ratio to GDP) | 1.26 | 0.22 | 0.20 |
| | | | |
| *Taxes* | | | |
| Statutory corporate rate | 0.38 | 0.11 | 0.08 |
| Effective marginal corporate rate | 0.23 | 0.10 | 0.07 |
| Effective average corporate rate | 0.28 | 0.09 | 0.06 |
| Personal tax revenue (ratio to GDP) | 0.11 | 0.03 | 0.03 |
| Corporate tax revenue (ratio to GDP) | 0.03 | 0.01 | 0.01 |
| Corporate tax revenue (ratio to capital income) | 0.07 | 0.03 | 0.03 |
| | | | |
| *Other* | | | |
| Investment (ratio to real GDP) | 0.20 | 0.03 | 0.03 |
| Capital's share of income | 0.34 | 0.04 | 0.03 |
| Average product of capital | 0.11 | 0.02 | 0.02 |

Table 2: Capital and taxes: correlations

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Capital* | | | | | | | | | | | | | |
| 1. Total capital (ratio to GDP) | 1 | | | | | | | | | | | | |
| 2. Government capital (ratio to GDP) | 0.42 | 1 | | | | | | | | | | | |
| 3. Housing capital (ratio to GDP) | 0.67 | −0.29 | 1 | | | | | | | | | | |
| 4. Business capital (ratio to GDP) | 0.89 | 0.29 | 0.46 | 1 | | | | | | | | | |
| *Taxes* | | | | | | | | | | | | | |
| 5. Statutory corporate rate | 0.41 | 0.10 | 0.33 | 0.35 | 1 | | | | | | | | |
| 6. Effective marginal corporate rate | 0.36 | 0.04 | 0.27 | 0.37 | 0.72 | 1 | | | | | | | |
| 7. Effective average corporate rate | 0.41 | 0.05 | 0.34 | 0.39 | 0.93 | 0.93 | 1 | | | | | | |
| 8. Personal tax revenue (ratio to GDP) | −0.01 | −0.35 | 0.12 | 0.14 | 0.00 | 0.07 | 0.04 | 1 | | | | | |
| 9. Corp. tax revenue (ratio to GDP) | −0.12 | 0.13 | −0.21 | −0.12 | 0.08 | 0.16 | 0.13 | −0.11 | 1 | | | | |
| 10. Corp. tax revenue (ratio to cap. inc.) | −0.37 | −0.69 | 0.15 | −0.32 | −0.22 | −0.20 | −0.20 | 0.27 | 0.28 | 1 | | | |
| *Other* | | | | | | | | | | | | | |
| 11. Investment (ratio to real GDP) | 0.25 | 0.51 | −0.28 | 0.36 | 0.00 | 0.13 | 0.06 | −0.29 | 0.23 | −0.44 | 1 | | |
| 12. Capital's share of income | −0.11 | −0.17 | 0.00 | −0.07 | −0.27 | −0.19 | −0.25 | 0.00 | 0.21 | 0.16 | 0.08 | 1 | |
| 13. Average product of capital | −0.81 | −0.34 | −0.56 | −0.70 | −0.51 | −0.40 | −0.49 | −0.02 | 0.20 | 0.32 | −0.07 | 0.60 | 1 |

Table 3: Regressions: accounting for capital-output ratios. This table reports regressions with our panel of countries over the period 1980-2004. Each is an estimate of equation (4) with a particular tax rate — or, in some cases, multiple tax rates. All tax rates are included as tax wedges: $(1-\tau)$ rather than $\tau$. Numbers in parentheses are t-ratios. The coefficients have the (approximate) interpretation as the elasticity of substitution between capital and labor. Some regressions include country fixed effects.

| Explanatory variables | (A) | (B) | (C) | (D) | (E) | (F) | (G) | (H) | (I) | (J) | (K) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Statutory corporate rate | −0.40 (−9.43) | | | | | | | | | | |
| Effective marginal corporate rate | | −0.34 (−6.16) | 0.14 (3.86) | | | | | | | | |
| Effective average corporate rate | | | | −0.55 (−8.60) | 0.16 (3.13) | | | | | | |
| Personal tax revenue (ratio to GDP) | | | | | | −0.03 (−0.15) | | | | −0.28 (−1.48) | −0.62 (−2.87) |
| Corp. tax revenue (ratio to GDP) | | | | | | | 1.20 (1.83) | | | | |
| Corp. tax revenue (ratio to cap. inc.) | | | | | | | | 1.38 (6.51) | 1.04 (6.99) | 1.45 (6.69) | 0.96 (6.44) |
| Country fixed effects | no | no | yes | no | yes | no | no | no | yes | no | yes |
| $R^2$ | 0.21 | 0.10 | 0.79 | 0.18 | 0.79 | 0.00 | 0.01 | 0.10 | 0.83 | 0.11 | 0.83 |
| BIC | −396.52 | −353.34 | −766.05 | −384.39 | −760.93 | −337.75 | −341.07 | −378.09 | −902.01 | −374.38 | −904.64 |
| Number of observations | 333 | 333 | 333 | 333 | 333 | 366 | 366 | 366 | 366 | 366 | 366 |

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Figure 1: Capital-output ratios. In the top panel, each line represents the total capital-output ratio for a specific country. In the bottom panel, the lines are the mean and standard deviation across countries.
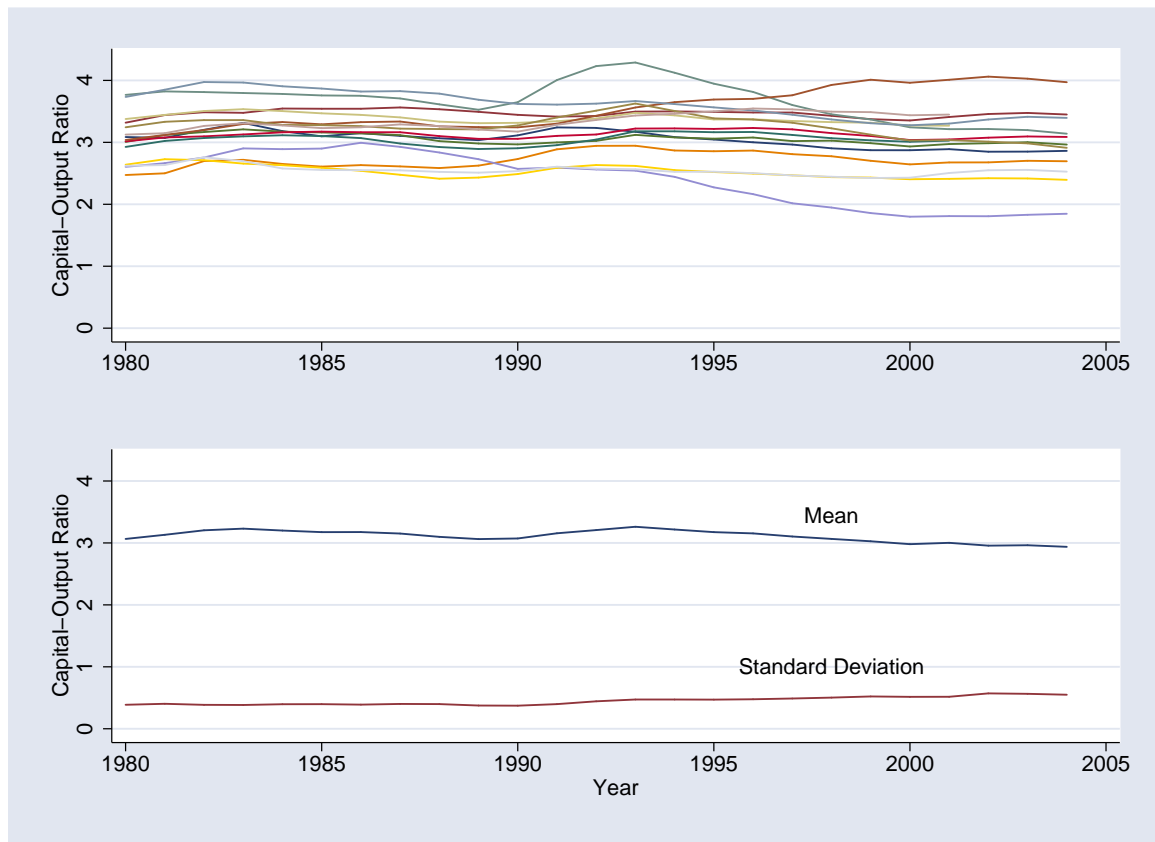
Figure 2: Effective marginal corporate tax rates. In the top panel, each line represents the tax rate for a specific country. In the bottom panel, the lines are the mean and standard deviation across countries.
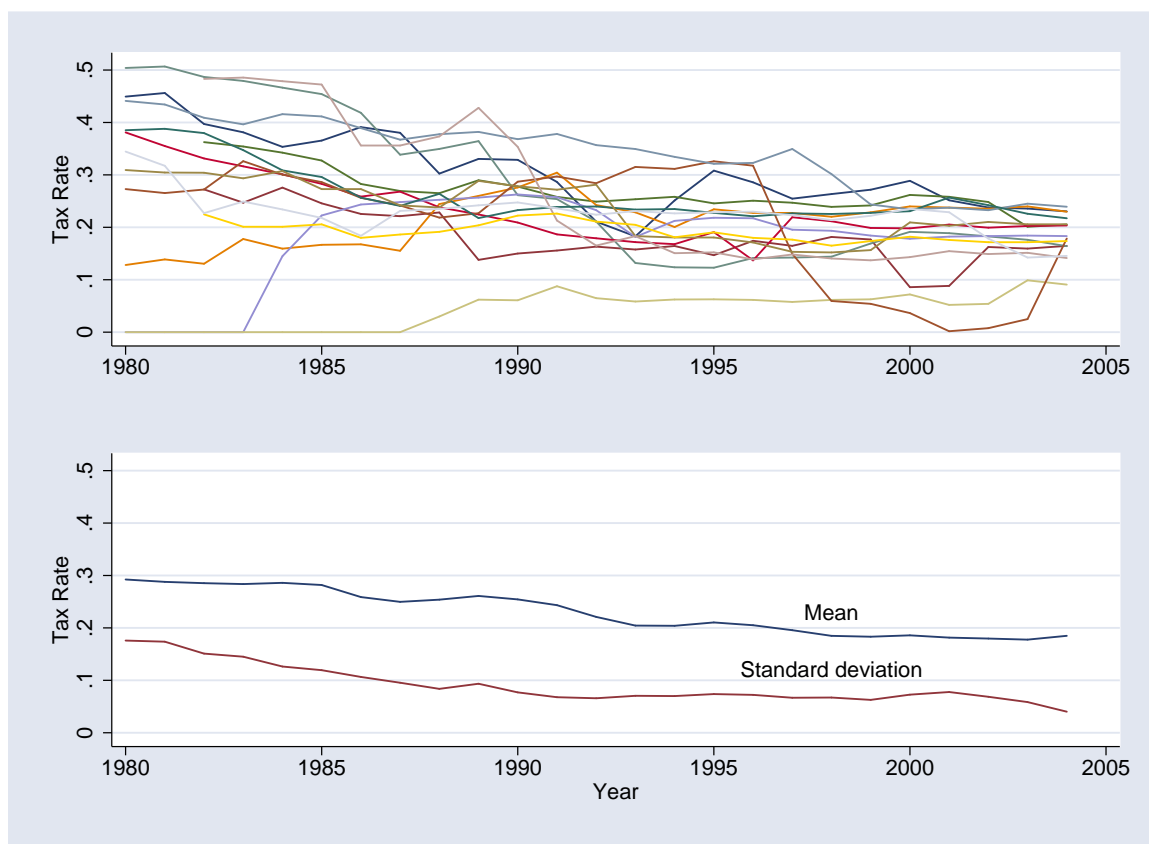
Figure 3: Revenue-based corporate tax rates. In the top panel, each line represents the tax rate (ratio of corporate tax revenue to capital income) for a specific country. In the bottom panel, the lines are the mean and standard deviation across countries.