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Corporate Taxation and Productivity Catch-Up: Evidence from 11 European Countries

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Abstract

Firms that lay far behind the technological frontier have the most to gain from imitating the technology or management practices of others. That some firms converge relatively slowly to the productivity frontier suggests the existence of factors that cause them to under-invest in their productivity. In this paper we explore whether higher rates of corporate taxation affect firm productivity convergence because they reduce the after tax returns to productivity enhancing investments for small firms. Using data for 11 European countries we find evidence for such an effect; productivity growth in small firms is slower the higher are high corporate tax rates. Our results are robust to the use of instrumental variable and panel data techniques with quantitatively similar effects found from a natural experiment following the German tax reforms in 2001.

Keywords: Productivity, taxation, convergence

JEL Codes: D24, H25, L11, O31

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1. Introduction

The existence of large differences in the level of productivity between firms within the same industry has stimulated what is now a significant body of research into the drivers of productivity change, and in particular the factors that encourage firms to imitate the superior technologies and management practices of those on the technical frontier.[1] There exist for example, numerous studies that have searched for evidence that non-frontier firms invest to improve their productivity because of the presence of foreign multinational firms (see Gorg and Greenaway, 2004, for a review), or intra-market (Foster, Haltiwanger and Krizan, 2001) and import competition (Schmitz, 2005; Disney, Haskel and Heden, 2003; Nicoletti and Scarpetta, 2005).

In this paper we contribute to the literature on firm productivity growth by testing whether aspects of the domestic policy environment, in our case corporate taxation, affect the productivity catch-up of firms.[2] All else being equal, those firms that lay the furthest behind the technological frontier would be expected to have the most to gain from imitating others and therefore be the most likely to make productivity enhancing investments (PEIs). These PEIs may include those in physical capital or in the creation of new knowledge through R&D, but are also increasingly likely to include complementary investments in intangible assets, such as management and organisation. Bloom and van Reenen (2007) provide strong evidence that higher-quality management practices, which they label organisational capital, are positively correlated with measures of firm productivity performance. Corporate taxation affects the incentive to make PEIs by reducing their post-tax return and thus the share of any increased profit appropriated by the firm (Arnold et al, 2011). For investments in physical capital this may affect productivity if new technology is embodied in capital. They may be further amplified because the tax system does not allow for the costs associated with investments in organisational capital to be offset against the firm's tax bill, as they are for machinery and equipment or patents and copyrights through depreciation allowances, and these are complementary to those in physical capital. [3]

There are also exists from the literature on capital investment a motivation to search for differences in the effects from corporate taxation on productivity across firms of different sizes. Keuschnig and

[1] Syverson (2004) shows that in the US firms near the top of the productivity distribution (the 90th percentile) produce close to twice as much output from an identical amount of inputs compared to firms that are near the bottom of the productivity distribution (the 10th percentile). In other countries these differences are even larger (Syverson, 2011).

[2] In studying the effects of tax policy on firm-level productivity change, we build on a literature that has examined the productivity effects of policy changes intended to stimulate greater competition or investment within an industry. This literature includes the effects of policy changes related to market regulation (Nicoletti and Scarpetta, 2005; Arnold, Nicoletti and Scarpetta, 2008), labour market flexibility (Petrin and Sivadasan, 2010) and trade liberalisation (Pavcnik, 2002; Bloom, Draca and Van Reenen, 2011). The evidence from this paper might be used to suggest that a wider range of aspects of the domestic policy environment are also relevant.

[3] Arnold et al. (2011) also argue that limited loss offset provisions result in relatively low risk-return projects being taxed at lower effective tax rates than risky projects that may yield higher returns in some states of the world. This again would tend to slow the rate of innovation.

Ribi (forthcoming) develop a model which draws upon the corporate finance literature to show how profit taxation affects the capital investment decisions of firms that are financially constrained. In their model profit taxes impair investment, not by raising the user cost of capital, although the work of Hubbard (1998) may suggest additional effects there, but by reducing pledgeable income. They argue that the relationship between the firm and outside investors is subject to information problems, which limits the amount of external funds firms can raise. A firm's capacity to raise credit depends on the amount of pledgeable income it can credibly promise as a repayment to banks. They show that for firms for which it is difficult or too expensive to obtain external finance, profit taxes reduce cash flow, and therefore pledgeable income, tightening financial constraints and reducing capital investment levels. They also show that efficiency costs are particularly severe when credit constraints are very tight, for example because the firm has few assets of its own. As small firms are more likely to be asset constrained and therefore credit constrained (Schaller, 1993; Aghion, Fally and Scarpetta, 2007) this suggests they are likely to have slower productivity catch-up as a consequence of higher taxation. Evidence can also be found which is consistent with the idea that the constraints on small firms may also lead to underinvestment of other types of capital, including organisational capital. Bloom et al. (2011) have shown that small firms have on average lower quality management practices than larger firms, where these management practices include the collection and analysis of performance information, as well as rewards for high performing workers and the retraining or firing of low performing ones. We consider whether small firms are more constrained by managerial capacity and time compared to large firms and therefore require higher returns from adopting these new work practices.

By studying the productivity effects of corporate taxation we build on the work of Arnold et al. (2011). Up until that paper, the productivity effects of taxation on firm behaviour had usually been inferred from their effects on indirect channels such as R&D and capital investment. The relationship between tax policy (mostly R&D tax credits) and the volume of, or the location of, R&D across countries/US states is reviewed in Hall and van Reenen (2000), while see Auerbach (2002), Gordon and Hines (2002), Hasset and Hubbard (2002), and Hines (2005) for the relationship between taxation and investment.[4] The work of Arnold et al. (2011) demonstrates that corporate taxation has a direct effect on firm productivity growth, lowering the growth of firms that are in more profitable industries.

[4] There also exists similar types of evidence for other aspects of firm performance such as entry and exit decisions, firm growth and reallocation across firms. See for example Rajan and Zinglaes (1998), Klapper et al. (2006), Griffith t al. (2007) and Batelsman et al. (2010). See Djankov (2009) for an excellent survey of the evidence on the effects of regulation on firm entry. See Da Rin et al. (2011) , Djankov et al. (2010) and Kneller and McGowan (2012) for evidence on the effects of taxation on industry entry and exit rates. Carroll et al (2000a,b) examine the effects of US tax reforms in the 1980s on the investment and hiring decisions of small businesses, finding significant effects.

Motivation for the idea that taxation may discourage productivity enhancing investments we draw on the work of Bridgman et al. (2009), who research the productivity effects of regulations in the US sugar market. Whilst the industry regulation they study extends beyond taxation to include restrictions on the entry of new sugar beet refiners and imports, one aspect of the policy environment they consider was the application of a income tax on sugar beet refiners (to pay for a subsidy for sugar beet farmers). They find that the productivity of sugar refiners, measured by the sugar-to-pulp ratio, fell as a result of the regulation of this market. This occurred in part because of the incentives for farmers to grow larger beets, which were as a consequence less sugar intensive, but also because the share of industry revenues that went to the refiners fell because of the tax. As a result of the latter the authors argue, refiners had little incentive to invest to maintain their equipment which lowered their productivity. We follow Bridgman et al. (2009) in studying the effects that higher taxation has on the incentive for firms to invest in their productivity, although here this incentive depends on the productivity gap rather than from regulation of an up-stream sector.

In studying the direct productivity effects of corporate taxation we follow Arnold et al. (2011), although we make a number of methodological changes compared to their work. The decision by Arnold et al. (2011) to study the between industry-differences in the effects of corporate taxation on firm productivity growth arises out of a concern for the possible effects of endogeneity bias on their estimation results; that the effects of corporate taxation reflect non-corporate tax policy factors or economic shocks omitted from the estimating equation. To deal with the effects of this bias they include country-time dummies in their regression equations.[5] This approach faces the conceptual challenge from Keuschnigg and Ribi (forthcoming) of explaining why all firms within an industry are similarly affected by corporate taxation and also why cross-industry differences are best captured by the profitability of the industry rather than some other characteristic. It might also be argued that this methodology reduces the usefulness of their results for policy. Whilst Arnold et al. (2011) provide strong evidence that firms in less profitable industries are affected differently to those in more profitable ones, they are unable to assess whether the overall effect of corporate taxation on productivity growth is positive, negative or zero.

We take an alternative approach and explore differences in the effects of taxation across firms within the same industry using the reduced form model of firm productivity convergence due to Griffith et al. (2009). In addition we use exogenous changes in taxation to identify its effects, considering the robustness of our findings to the use of both an instrumental variable approach and

[5] The country-time dummies are perfectly collinear with the corporate tax variable of interest, hence they follow the approach of Rajan and Zingales (1998) in using industry interaction terms.

using a 'natural experiment' in the data. Drawing on the tax competition literature, to identify exogenous components of taxation we follow Devereux et al (2008) and create instruments based on the tax rates of other European countries. We find that these strongly predict the tax rate of a country and lead to an increase in the estimated effect of corporate taxation. The exogenous tax event that we examine is the 13 percentage points reduction in corporate tax rates that occured in Germany between 2000 and 2001 and used previously by Becker et al. (2006) to identify the effects of tax reform on investment by foreign affiliates. Becker et al. (2006) describe the motives behind this tax reform as attracting FDI, encouraging investment and to adapt the German tax system to the rules of the EC Common Market.[6] We also show that our results remain similar if we take the approach of Arnold et al. (2011) and flood the regression with control variables, including country-time dummies and fixed firm effects.

Using an unbalanced panel of manufacturing and service sector firms from 11 European countries over the period 1996 to 2005 we find evidence that corporate taxation has significant effect on the productivity growth of small firms that are furthest from the technological frontier. The ability of small firms to catch-up with the best firms in their industry and country is slowed by higher rates of corporate taxation. This indicates that taxation exacerbates the managerial and financial constraints faced by small firms. Consistent with a view that large firms are not constrained, we also show that our results do not hold for large firms, even ones which have low productivity. We also show that that the results are robust to the use of a measure of small business taxation (as used by France, Spain and the UK); measures of the forward looking effective marginal corporate tax rate for machinery and equipment investment due to Devereux and Griffith (1998, 2003); as well as the introduction of various country, industry and time variables and dummy variables; the introduction of firm fixed effects, to control for time invariant firm-specific differences such as managerial ability; and for country-industry differences in the rate at which firms catch-up with the productivity frontier. They are also robust when we use an IV strategy or when we focus on the 2001 German tax reforms. In these latter regressions we again show that there are no similar effects for large firms and are robust to the inclusion of firm fixed effects, but also that they are unaffected by the choice of counterfactual. We find similar outcomes for the productivity growth of small German firms irrespective of whether we use other German firms, or small firms in other countries where there was no tax change (Sweden, Spain and the UK), as a counterfactual. We conclude from the robustness of our findings to the array of empirical methodologies that we use that the results

[6] In this regard, the paper complements the evidence of the effects of changes to corporate taxation and depreciation allowances on investment using a natural experiment approach by Cummins et al. (1994, 1996) and House and Shapiro (2008).

appear consistent with a causal relationship from corporate taxation to productivity catch-up by small firms. Higher corporate tax rates reduce the returns from PEIs, lowering productivity growth.

Finally, we note that the effects we find for corporate taxation are economically significant. Our results suggest that compared to a counterfactual of no-change in the corporate tax rate, the effect of German tax reforms was to raise the productivity growth rate for a small firm with a productivity gap 75% of the frontier firm by 2.2 percentage points. Similar sized effects are found from the other estimations that we undertake. To provide some further context to that figure, Lileeva and Trefler (2010) report that the country's entry into NAFTA increased the productivity of Canadian manufacturing firms by 3.5%.

The rest of the paper is organised as follows. In Section 2 we outline the econometric model that we use to estimate the effects of corporate taxation. Section 3 outlines the data and some key characteristics of the data. Section details the main results of the paper. Section 4.1 describes the baseline estimates and we use sections 4.2 to 4.5 to test their robustness. Finally, we draw some conclusions from the study in Section 5.

2. Model and Econometric Strategy

In order to motivate the empirical section of the paper we begin by developing a reduced form model of productivity convergence. This draws closely on the work of Griffith et al. (2009) and Lileeva and Trefler (2010) and we make the modest extension to add corporate taxation. We assume that output in firm *i* in industry *j* in county *c* at time *t* is a function of the production technology set out in equation (1), where the *A* term measures total factor productivity (TFP) of the firm and *K* and *L* measure the factor inputs physical capital and labour. Equation (1) is assumed to exhibit diminishing marginal returns in each of the factor inputs and is allowed to differ across industries and countries.

$$Y_{ijct} = A_{ijct} f_{jc}(K_{ijct}, L_{ijct}) \tag{1}$$

Based on the evidence presented in Coe and Helpman (1995), Eaton and Kortum (1999), Keller (2001a, 2002) and others, the TFP of a firm is assumed to be a function of new knowledge that pushes forward the technical frontier, labelled TF_{jct}, as well as efforts to improve productivity by increasing efficiency or imitation, D_{ijct}. Formally, $A_{ijct} = g(D_{ijct}, TF_{jct})$. Firms that undertake product and process innovation through R&D as well as intangible forms of innovation, such as those in management or product design, are assumed to help push forward the technical frontier.

Our focus in this paper is on the determinants of D_{ijct}. We assume that these imitative productivity efforts are an increasing function of the size of the productivity gap. Those firms furthest from the technological frontier have the greatest scope for imitation of the superior technologies used by others and would be expected to grow more quickly than firms for which there is less scope for imitation. Following evidence from Bartelsman, Haskel and Martin (2008) we assume that firms converge upon the productivity level of the domestic leader in their industry.[7]

As in Lileeva and Trefler (2010) we assume the process of productivity convergence does not occur automatically, but rather firms must invest to raise their productivity. These might be large investments, where the firm takes a substantial leap-forward in its choice of technology, or small changes at the margin. To capture this we assume PEIs include those in intangible assets such as organisational capital (Bloom and Van Reenen, 2007, 2010) and improvements in the quality of human or physical capital such as IT (Ilmakunnas, Maliranta and Vainiomäki, 2004; Jogensen, Ho and Stiroh, 2005, 2008; Oliner, Sichel and Stiroh, 2007). In all cases we assume that these PEI's are costly to the firm, although they might be thought of as an increasing function of the size of the investment. These costs might include the disruption costs a firms incurs from new technologies or work practices, such as installation problems, fine-tuning the new technology and retraining workers (Holmes, Levine and Schmitz, 2008). They may also reflect the credit constraints faced by firms when trying to raise external funds (Keuschnigg and Ribi, forthcoming). We bring together these ideas by assuming that the firm can raise its productivity from A_0 (its initial productivity level) to A_1 (where $A_1 > A_0$) but to do so must pay a fixed cost F. It follows that the returns to productivity enhancing investments differ for each firm according to the size of their initial productivity gap and that they will only choose to invest if the productivity gains are above some critical threshold level, given by the fixed cost. Those firms with little to gain from the investment, that is, the gap between A_0 and A_1 is small relative to the fixed cost, will not invest and will operate below the productivity frontier. If the scope and range of investments are increasing in the range of technologies that can be imitated, then firms with a large knowledge gap will be more likely to make the investment.

Whilst convergence of productivity levels from below is a feature that we find in our cross-country firm-level data, and has been found in other micro datasets by Bartelsaman, Haskel and Martin (2008), Griffith, Redding and Simpson (2009) and others, a number of papers also find evidence that the rate of convergence differs across firms. This suggests that there are further factors that

[7] Bartelsman et al. (2008) find that firms converge more quickly to the domestic-industry frontier than the global-industry frontier, suggesting that the former may the more important source for imitation. This assumption has the convenient property that it does not require us to transform the cross-country data to a common currency in order to compare the productivity of firms. Such comparisons are sensitive to the choice of exchange rate. We test the robustness of our results to this assumption by including in some regressions (see Table 9) industry-time dummies, which will capture movements of the global-industry frontier.

constrain the ability of some firms to make imitative investments. In this paper we explore whether this occurs because the constraints on finance and management for small firms F are higher, so that small firms require higher returns from their investments compared to large firms. For these firms, managing the adjustment costs associated with productivity improvements takes a greater relative share of available managerial time. As Arnold et al. (2011) note, if successful innovations are measured by the net-of-tax rate of return, then to the extent that tax parameters drive a wedge between a firm's gross and net returns, they can be expected to discourage that innovative activity. That in turn impacts negatively on a firm's ability to improve its productivity levels, other things equal. In principle this applies to both incorporated and unincorporated enterprises – such that the relevant tax parameters will differ in each case depending on these enterprises' liabilities under personal, corporate and other tax schedules. In our empirical work we focus on incorporated firms so that it is the impact of effective rates of corporate tax that are most relevant. The share of additional profits appropriated by the firm is therefore lower in high tax settings, in much the same way that the literature on physical capital investment suggests that higher corporate taxes will depress capital investment. We anticipate that these constrained and highly taxed firms will make fewer, smaller and less-risky investments to improve their productivity, so that the speed of convergence to the productivity frontier will be slower. If capital investment is reduced they are also less likely to make complementary investments in organisational capital, magnifying the effects of taxation. To summarise, the internal sources of productivity improvement are therefore an increasing function of the initial TFP gap, but a negative function of the corporate tax rate (T_{ct}).

To account for the fact that productivity enhancing investments, such as those in organisational capital, cannot be observed in the data available to us, we estimate a reduced form model of productivity convergence and taxation with an error correction structure set of out in equation (2). Aside from the addition of the terms capturing the effects of taxation this equation is identical to that estimated by Griffith et al. (2009).

$$\Delta \ln A_{ijct} = \alpha + \alpha_0 \Delta \ln A_{Fjct} + \alpha_1 \ln\left(\frac{A_{ijct-1}}{A_{Fjct-1}}\right) + \alpha_2 \ln\left(\frac{A_{ijct-1}}{A_{Fjct-1}}\right) * T_{ct-1} * D_{SIZE_i} + \varepsilon_{ijct} \qquad (2)$$

The parameter α_0 in equation (2) captures the instantaneous effect on all firms of changes in the productivity frontier where, as mentioned already, this is the domestic-industry frontier. The productivity gap for a firm is measured by the ratio of firm productivity to the domestic-industry frontier at time t, such that the parameter α_1 measures the speed at which firms can close this gap. We anticipate that α_1 will be negative, the greater the size of the initial productivity gap the faster a firm would otherwise be expected to grow. It follows that the parameter α_2, which captures the effects of taxation for small firms will be positive, as these factors are expected to slow the rate at which this convergence occurs. The variable D_{SIZEi} is a dummy variable equal to one when the firm has fewer than 20 employees. We test the robustness to that definition of small firms in section 4.

As we describe in more detail below, the data on taxation we use is measured at the country-time level. An important concern in the estimation of equation (2) is the effects of endogeneity bias on our tax variables, explained by the omission of important variables that are correlated with these country-time factors and the error term in the regression. We test for the possible effects of this bias in the main estimation results, by adding various combinations of country, industry, year variables, time-varying country factors, country-time dummies, an instrumental variable approach and an exogenous tax event in Germany. We discuss the effects of these different strategies as well as any additional control variables in more detail in Section 4 of the paper.

3. Data Description and Summary

Our firm-level data is taken from the Amadeus database (Bureau van Dijk) and covers 11 European countries for the years 1996-2005. To reduce the number of observations available in the dataset to a level manageable for estimation, we follow Schwellnus et al. (2009) and apply a retrospective sampling. To perform this sampling we use population weights for each size-sector-country strata from the OECD's Structural and Demographic Business Statistics database for 2003. As in, Arnold et al. (2011) we restrict the analysis to firms in manufacturing and service sectors (Nace 15-93) and exclude firms with missing data and obvious key punch errors prior to the re-sampling. We also exclude observations from the agricultural, forestry and mining sectors as well as service sectors such as education and health services where public provision is more likely and corporate taxation is usually not applicable. The final sample is both smaller in size than the original Amadeus database and does not suffer from the same size-bias towards large firms.

The loss of firms without the necessary information on inputs when constructing our measure of TFP results in a final sample that is unbalanced across countries and time. In order to concentrate on the determinants of productivity catch-up, we further restrict the analysis to non-frontier firms. The sample used in the estimation covers around 226,000 observations on some 54,787 firms. The country coverage differs, depending upon the coverage within the Amadeus database, and within the final sample ranges from just 100 observations for Austria up to close to 88,000 for Italy. The larger European countries are particularly well represented. In addition to the 88,000 observations for Italy, there are around 8,000 observations for France, 23,000 for Germany, 48,000 for Spain and 32,000 for the UK. Around 88% of all observations are therefore from these 5 countries. The data are also unbalanced across time. The loss of firm information is greater the further we move away from the base year of 2003. There are over 40,000 observations in each of the years 2003, 2004 and 2005 but less than a thousand observations in 1996 and 1997. The number of observations per year is displayed in Table 1, while the number of observations per country can be found in Table 3.

To construct measures of productivity for each firm and the productivity frontier we estimate a production function at the country-industry level, such that firms' technologies can differ by country and industry. We then estimate TFP applying the semi-parametric method proposed by Levinsohn and Petrin (2003). This method allows the production function input parameters to be estimated while allowing for the possibility of an endogenous response of productivity to unobserved shocks.[8] The productivity frontier in each country-industry-time period is approximated by the firm that lies on the 95th percentile of the TFP distribution. The 95th percentile is chosen to reduce the possibility that extreme data points caused by measurement error affect the results.

In Table 2 we report basic summary statistics for the rate of TFP growth across firms and countries, along with the growth rate of the productivity frontier and the average TFP gap with frontier firms. Table 3 provides greater detail on the distribution of the TFP gap for the different countries that make up the sample, including the average TFP of firms with less than 20 employees. The average rate of TFP growth in the sample is 2.7 per cent per annum. This is faster than the growth rate of the productivity frontier (average rate of growth 1 per cent per annum), which suggests that the average firm converges towards the frontier over time.

The average TFP gap compared to the domestic-industry productivity frontier is 79 per cent. Table 3 suggests there is considerable heterogeneity in the size of this gap across countries. For example, firms in Germany operate consistently closer to the domestic technological frontier than say firms in France or the UK.[9] The average firm in Germany has an estimated TFP that is 89 per cent of the best firms there, whereas for France the average firm has a TFP that is 66 per cent of the best firms in France. For the UK the figure is 80 per cent. The average TFP gap of small firms is below the average TFP across all firms in every country except Italy and Portugal. In some cases the difference between the TFP gap for small firms and the average across all firms is large. In Germany for example, the average TFP is 89 per cent of the frontier firm, but 83 per cent for small firms.

Table 3 also provides information on the dispersion of TFP across firms in each country. More generally it would appear that countries such as France, Italy and the UK have a longer tail to the

[8] The Levinsohn and Petrin (2003) estimator uses intermediate inputs as investment proxies, arguing that these may proxy for the unobservable productivity shock. However, the method requires additional information on firms' use of material inputs, thus reducing the sample.

[9] As the production function is estimated separately for each country and industry the estimates of TFP do not provide information on the level of TFP across countries or industries. The results cannot therefore be used to determine whether firms in Germany are more or less productive than those in France for example.

distribution of TFP compared to Germany. The firm at the 25th percentile of TFP has a TFP level that is 85 per cent of the most productive firms in Germany, whereas in France it is 60 per cent, 65 per cent in Italy and 69 per cent in the UK. According to Table 3 the weakest TFP performance would appear to occur in Czech Republic and Denmark. Here the TFP of the average firm compared to the productivity frontier in these countries is 58 and 61 per cent respectively, while the TFP of the firm at the 25th percentile is 39 and 43 per cent respectively of the best firms.

[Insert Table 1]

[Insert Table 2]

[Insert Table 3]

The data for statutory corporate tax rates we use are obtained from EUROSTAT, *Taxation Trends in the EU*. In Table 4 we report the statutory corporate tax rate for each country averaged between 1996 and 2005, along with the change in the tax rate over that time period. We use the statutory tax rates because of their comparability across countries. As we use data only for incorporated firms, statutory corporate tax rates are also likely to be used as the bench-mark by which to determine the returns to PEIs (Djankov et al., 2010). They are also the relevant marginal tax rate for investments in assets, such as many intangibles, for which there is no provision in the tax system for the costs of depreciation. We test the robustness of our results to this measure of corporate taxation by also considering the forward looking effective marginal and average tax rates constructed by Devereux et al. (2002) in Section 4.2. These effective rates are hypothetical forward looking tax rates applicable to specified investment in plant and machinery undertaken under alternative assumptions regarding, for example, the relevant rate of interest, inflation rate, method of financing (debt, equity) etc. They therefore provide an example of effective tax rates assuming that the productivity enhancing investment made by the firm is in machinery equipment.

According to the information presented in the table, the highest average corporate tax rates are in Germany, 45.5 per cent, and Italy, 43.3 per cent. The corporate tax rates in the remaining countries range between 28 per cent (Sweden, Finland) and 37 per cent (France). Also important for the effects we identify are the changes in taxation across years. The corporate tax rate has fallen over time in most countries in the sample, with the largest falls in Germany (18 percentage points), Czech Republic and Italy (15 percentage points), Portugal (12.1 percentage points) and Austria (9 percentage points). In contrast in Spain and Sweden the corporate tax rate in 2005 was the same as in 1996, and in Finland it was 1 percentage point higher. Of the countries for which we have most data, the majority of changes in the rate of corporate taxation are relatively modest, in the order of 2-4 percentage points per year. An exception is Germany where the tax rate was reduced by 13 percentage points to 38 per cent between 2000 and 2001. We focus on the effects of the tax reform in Germany as a test of the robustness of our findings in Section 4.4.

[Insert Table 4]

4. Empirical Evidence

In this section of the paper we report the results from the estimation of equation (2) and provide some discussion of the magnitude of the effects that we estimate. Some general issues of robustness are explored in section 4.2, while the results from the IV regressions and 2001 tax reform in Germany can be found in Sections 4.3 and 4.4 respectively.

4.1 Baseline Estimates

Regression 1 of Table 5 represents the most parsimonious regression that we estimate. The regression includes a measure of the growth of the technological frontier, the firm-specific gap with this frontier (denoted TFP gap in the table), and a set of time-dummies. These time-dummies control for shocks common across the European countries, for example the point in the business cycle. Following evidence from Arnold et al. (2011) that profitability matters for productivity growth, we also include in the regression a variable which considers whether the rate of convergence is affected by the profitability of the industry, and whether this rate of convergence is faster or slower for small firms. Here we hypothesise that profitability might either act as a spur to make productivity enhancing investments or, if these investments are paid for out of retained earnings, rather act to slow the rate of convergence by firms. To ensure that we capture the inherent profitability of an industry rather than any effect that higher corporate tax rates in a country might have on this variable, we follow Arnold et al. (2011) and use (time invariant) industry-level data on profitability for the US to proxy for this.[10]

The results for the variables measuring the effects of the TFP gap and the growth of the frontier compare favourably with those from elsewhere in the literature. Growth of the productivity domestic-industry frontier is found to have positive spillover effects upon the growth of firms operating behind the frontier (see Griffith et al. 2001, 2003 for similar evidence). The magnitude of the coefficient indicates this effect is relatively strong. When the frontier grows by 1 per cent,

[10] The US is chosen as the country from which to derive this industry variable as its firms are subject to lower tax rates and fewer policy restrictions compared those in Europe and because it is not included in the sample. Information on the profitability of industries is calculated from the 2002 U.S. Benchmark Input-Output Data Table (*U.S. Bureau of Economic Analysis*, 2002). For each industry at the 2-digit ISIC level a profitability ratio is calculated from data on gross operating surplus divided by value added; this is applied to the whole period of our analysis, 1998-2005.

productivity in non-frontier firms grows by 0.335 percentage points. The results from regression 1 also show that the rate of productivity growth is higher the greater is the distance between the firm's productivity and that of the (domestic-industry) frontier. As expected firms that are far behind the productivity frontier have greater scope to imitate the technology of others and therefore catch-up with the best firms over time.[11] The rate of growth the firm experiences depends of course on the size of its initial productivity gap. According to the summary statistics in Table 3 the average productivity of non-frontier firms relative to the productivity frontier is 79 per cent. For this average firm, the rate of productivity growth would be 1.7 percentage points per annum faster than a firm with a productivity level 85 per cent of the frontier firm, and around 4.3 percentage points per annum faster than a firm with a productivity level 90 per cent of the frontier firm.[12] The evidence in regression 1 also indicates that small firms in industries with low-profitability actually appear to converge more, and not less, quickly to the technological frontier, although there is no significant effect from this variable on the rate of convergence for larger firms.

[Insert Table 5]

We also examine in regression 1 the role of taxation in shaping the rate of productivity catch-up for small firms (defined according to whether employment is more or less than 20). By including the interaction between taxation and a measure of the distance to the productivity frontier, we consider a more general model of the effects of taxation than the existing literature on productivity convergence. From regression 1 we find no evidence for such an effect, the corporate tax-TFP interaction term is insignificant for small firms. Corporate taxation does not significantly change the rate at which small firms invest to close the productivity gap, with weak evidence that it might actually increase this rate. Whilst, this is consistent with a view that higher corporate taxation encourages firms to work-harder to improve their productivity, the remaining regressions in Table 5 indicate that this conclusion is driven by omitted variables.

According to the tax competition literature, countries that are large typically have higher corporate tax rates than small countries because firms are attracted to large markets and this outweighs the negative effects of taxation on their location choices. If higher corporate tax rates lead to the weeding out of weak firms, such that only the best firms can survive in the industry, and these better firms have faster rates of productivity growth, then this might explain the negative sign on the interaction term between corporate tax rates and the TFP-gap variable in regression 1. Alternatively, higher corporate tax rates may be correlated with some other omitted aspect of the business

[11] Similar evidence exists at the aggregate (Bond et al., 2001), industry (Griffith et al., 2001) and firm level (Griffith et al., 2003).

[12] These results are unchanged when we use an Olley and Pakes (1996) based estimate of firm TFP.

environment of a country, such as infrastructure expenditure, which again would increase the rate of convergence. In regression 2 we assume that these omitted country and industry factors are time invariant in nature and test the sensitivity of the results in regression 1 to the inclusion of country and industry dummies.[13] The inclusion of country effects has an important impact on the results for the TFP gap-corporate tax interaction term for small firms. The significant positive coefficient on this interaction variable indicates that higher corporate taxation slows the rate at which these firms converge to the productivity frontier. This result is consistent with an interpretation that higher taxation reduces the net present value (NPV) of future investments for small firms, such that they invest less in productive technologies.

How large are the tax effects we find? In Table 6 we use the coefficient estimates from regression 2 to compare the rate of productivity growth of small firms in different tax settings. In the table we compare the growth rate of a small firm with a productivity level equal to 75%, 85% and 95% of the frontier in their country at different rates of corporate taxation (25%, 30%, 35%, 40% and 45%) compared to a firm that faces a corporate tax rate of just 20%. These tax rates are chosen as representative of the corporate tax rates across the countries that make up our sample. The tax rate of 40% is close to that for Germany and Italy at the end of the sample period, France had a tax rate of 35% by the end of the period, the UK around 30% and Austria 25%. No country in our sample had a statutory corporate tax rate of 20%, but this figure is an upper bound on the tax rates found in low-tax European countries not in the sample, such as Ireland and Switzerland.

The table shows that for a small firm in a country with corporate tax rates of 25% and with a productivity level 75% of a frontier firm, productivity growth is 0.3 percentage points per annum slower compared to that estimated for the same firm facing a corporate tax rate of 20%. In a high tax country, the corporate tax rate is 40%, productivity growth is 1.2 percentage points slower than the firm facing a corporate tax rate of 20%. The effects of taxation become quantitatively less important the closer the small firm is to the productivity frontier. For firms with a productivity level equal to 95% of the frontier, operating in low tax environments (the corporate tax rate is 25% compared to 20%) the difference is only 0.11 percentage points. As the difference in corporate tax rates increases (the corporate tax rate is 40% compared to 20%) growth is reduced by 0.5 percentage points.

4.2 Robustness Issues

[13] We also add fixed industry effects to control for any time-invariant industry-specific factors.

Before moving on to consider the effects of endogeneity bias on our results for the corporate tax-TFP gap variable, in this section we examine the implications for assumptions made about firm size, make an allowance for the use of small business tax rates in some countries and use measures of effective rather than statutory tax rates.

Two questions that might be raised about the robustness of the effects of corporate taxation in regression 2 are a) whether they in fact capture the effects of corporate taxation on all firms rather than just small firms, and b) whether they are driven by differences in the rate of convergence between small and large firms and taxation plays no role. We consider the answers to those questions in regressions 3 and 4 in Table 5. To test for the former, in regression 3 we add alongside the corporate tax-TFP gap interaction for small firms, the same variable for all firms (TFP gap*Corp. Tax.). In this regression the coefficient on the tax-gap variable captures the effect of taxation on convergence of firms irrespective of their size, while the tax-gap-size interaction (TFP gap*Corp. Tax.*D_{SIZE}) tests whether the effect for small firms is different from this general effect. In regression 4 to test whether the rate of convergence differs for small firms independent of any effect that corporate tax rates might have, by including an interaction between the small firm dummy (D_{SIZEi}) and the TFP-gap variable. In both regressions we find that the main results in regression 2 are robust to this change. In regression 3 we find no significant effects of taxation on all firms, the tax-TFP gap variable is insignificant, but that taxation affects convergence by small firms. It would appear from this result that only small firms are constrained in their ability to make productivity enhancing investments and are therefore sensitive to corporate tax rates, whereas large firms are unaffected. In regression 4 the results indicate that the rate of convergence is faster for small firms compared to large firms, conditional on the tax-gap variable for small firms. This is consistent with a view that small firms are highly innovative and enjoy, in the absence of credit constraints, fast rates of productivity growth.

[Insert Table 6]

In regression 5 we test whether the results from Table 6 are sensitive to how we classify small firms, by using an alternative cut-off of 50 employees. We find that the coefficient on the TFP gap-tax interaction term remains significant in this regression and as expected the point estimate falls in size relative to that estimated in regression 4. When we test whether the effect of corporate taxation on firms with 20-50 employees is significantly different from that found for firms with an employment level less than 20, we cannot reject the null hypothesis that they are similar though.[14] We conclude

[14] To perform this test we create a new tax-TFP gap variable for firms with employment between 20 and 50 employees and then test for the significance variable when the tax-TFP for firms with between 1 and 50 employees is also included in the

from this that the effects of corporate taxation on the productivity catch-up of firms with between 20 and 50 employees is statistically similar to that for firms with employment less than 20 and therefore the effects of corporate taxation are broader than first thought.

The constraints on small firms, for example in their access to finance compared to large firms, have long been recognised by policy makers and as a consequence some countries, such as the UK, France, Spain and Portugal, have attempted to alleviate the effects of these constraints by lowering the corporate tax rate for small firms (Nam and Radulescu, 2007). In some cases these differences can be large. For example, in the UK the small business corporate tax rate in 2003 was 19% compared to the standard rate of 30%. In regression 6 we replace the standard corporate tax rate for that applied to small firms in France, Spain, Portugal and UK. Interestingly, this has little effect on the coefficient magnitude for corporate taxation and the variable remains statistically significant.

[Insert Table 7]

In our use of the statutory corporate tax rate we have both ignored the possibility that the ranking of productivity enhancing investment opportunities will change because of different depreciation allowances for different types of capital (Devereux and Griffith, 2003) as well as progressivity in the corporate tax rate schedule across time introduced by loss offset provisions (Arnold and Schwellnus, 2008). We have also ignored the role played by taxation of other forms of income, such as personal taxes on interest income and capital gains, which may be relevant when determining the method of financing for investments for incorporated firms (Devereux and Griffith, 2003). To model this in regression 7 we replace our measures of the statutory corporate tax rate with forward looking effective rates from IFS/Devereux *et al.* (2002). These effective rates are hypothetical forward looking tax rates applicable to specified investment in plant and machinery undertaken under alternative assumptions regarding, for example, the relevant rate of interest, inflation rate, method of financing (debt, equity) etc. These are available as both average and marginal rates for each year for all of the countries in our sample except for Denmark and the Czech Republic. As well as arguably reflecting more closely the actual tax rates faced by firms, albeit based on a particular set of assumptions about the type of investment, method of financing etc., the forward looking nature of these tax rates have the additional advantage that they might reasonably be regarded as exogenous to economic shocks.

The average rate is the tax rate relevant for discrete investment choices of the type we examine: whether to make an investment or not (Devereux and Griffith, 1998, 2003) so we anticipate this will slow the rate of productivity convergence for small firms. For the marginal tax rate the relationships

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regression. The coefficient on tax-TFP gap variable for 20-50 employees is equal to 0.15 with a t-statistic (p-value) of 1.24 (0.214).

are potentially more complicated. Given the high correlation between the marginal and effective tax rates in the data (the raw correlation is over 85%) we cannot separately capture the effect of a higher average tax rate from that of a higher marginal rate. We use instead the difference between the effective average and marginal rates. It might be expected that this measure of taxation will pick up several effects. Firstly, it may capture the effects of changes in depreciation allowances. As depreciation allowances are reduced, the average and marginal tax rates become more similar which discourages investments. We might therefore expect an increase in the difference in the average and marginal rates to increase the rate of catch-up. Alternatively, higher marginal tax rates can also reflect an absence of loss offset provisions and affect the risk taking by firms (Arnold and Schwellnus, 2008). Risky innovative projects, which have a probability of yielding large productivity gains, have a higher effective marginal tax rate when no provision for possible losses is allowed for in the tax system. Here we anticipate that the closer the average becomes to the marginal tax rate, their difference falls towards zero, the greater are loss offset provisions, and the more likely it is that firms will undertake risky innovative projects.[15] We would therefore expect that the coefficient on the difference in tax rates will be positive in this case.

The results for these additional tax variables are shown as regression 7 and suggest that the latter effect dominates for small firms. We find that an increase in the interacted effective average tax rate slows the rate of productivity catch-up for small firms, as does the difference between the average and the marginal rates. We conclude from these results that higher average tax rates slow the rate of productivity catch-up by small firms, as does greater progressivity in the corporate tax schedule.

4.3 Endogeneity Bias

In the regression results presented from regression 2 (Table 5) onwards we control for time-invariant features of a country that may affect the rate of productivity growth of firms, so that the effects of taxation are identified by their effects within countries. But, what if there are time-varying omitted country factors that are correlated with corporate taxation and productivity contained within the error term? It might be the case for example, that governments which choose high corporate tax rates have higher expenditures on infrastructure (including road, rail and ICT), which would tend to increase the productivity of firms in that country. If these expenditures affect firms that are furthest from the technological frontier then this would tend to bias the effects of taxation

[15] To give the example used in Arnold et al. (2011), consider two projects yielding the same expected return r. The first project yields this with certainty, while the second project yields either 3r or –r with equal probabilities. With no loss offset provisions and a corporate tax rate of 30% the after tax return is 0.7r for the safe project and 0.55r for the risky project. The return is therefore greater for the safe project, despite the fact the tax rate is identical.

that we capture towards zero. Alternatively, high corporate tax rates may indicate a general desire by some governments to regulate businesses, which may reduce the rate of productivity growth of firms within a country (Tybout, 2003). If these anti-business policies are difficult to measure, then this would tend to reduce the rate of productivity growth and may increase the size of the estimated coefficient on the corporate tax variable. Whichever is the most relevant explanation, it is worth noting that because we find no effect from corporate taxation on convergence by large firms, this omitted variable bias can only occur because of an effect on convergence by small firms. Our first approach to dealing with this potential issue is to add a series of political and additional fiscal controls.

In regression 8 (Table 7) we consider whether the results found so far are explained by the omission of difficult to observe policy variables by adding control variables that capture various time varying aspects of the political make-up of a country. Here we assume that left- versus right leaning governments will affect the business environment of a country in different ways, and that tax policy may be affected by the point in the political cycle. The political variables we include are the number of years the chief executive has spent in office, the number of years left in the current term, the vote share of the largest political party and whether the party of the executive controls all houses. We also control for whether the country has a proportional representation system as well as a measure of political decentralisation (whether there are autonomous regions), the mean district size of the House and Senate and the checks and balances in place. Lastly we add a measure of total government expenditures and government revenues as a ratio to GDP. Here we assume that the omitted policy variables that might contaminate our results are reflected in the level of fiscal expenditures or tax and non-tax revenues within the country. In this regression we continue to include country, industry and time-dummies and, given the results in regression 4, allow the rate of convergence to differ between small and large firms. To conserve space we report only the main variables of interest and indicate in the table which other variables have been included. The data on the political variables are from the World Bank's Database of Political Institutions database and data for government expenditures are from the IMF Government Financial Statistics data set.

The results suggest that omitted policy variables were of modest concern. A number of these political controls are statistically significant as are the government expenditure and revenue variables, but the main findings are robust to the inclusion of the political and fiscal variables in regressions 8. [16] We continue to find evidence that productivity catch-up is slower for small firms in

[16] The coefficients (t-statistics) on the number of years spent in office 0.0001(0.62), years left in office -0.004 (0.70) and a dummy for whether there is proportional representation -0008 (0.18) are all statistically insignificant, while those for the vote threshold 0.00007 (5.74), if party of executive controls all houses -0.014 (4.90), mean district size of house 0.00003 (5.62), checks-and-balances (0.09 (2.21), vote share of the largest government party 0.001 (1.63) and a dummy for

high corporate tax settings. Moreover the addition of these controls changes the magnitude of the coefficient by very little.

During the recent global macroeconomic crisis countries adopted a variety of fiscal responses in an attempt to stimulate growth in the economy. These included temporary tax-cuts early on in the crisis and then emergency tax raises in response to growing fiscal deficits. This reveals that tax rates are often adjusted in response to the macroeconomic shocks faced by a country, where these shocks are also likely to have a productivity impact. If these external shocks have different effects on small and large firms, or according to the size of their productivity gap, then it follows that it may be the effect of these shocks that we capture in the regression rather than corporate taxes. It also seems likely that the political and fiscal variables do not properly control for this source of bias. Our previous findings are therefore possibly not free of endogeneity bias.

One solution to this problem requires the identification of a variable (an instrument) that affects the timing and the size of any tax changes, but not the rate of productivity growth by firms within a country. In regressions 9, 10 and 11 in Table 8 we draw on the tax competition literature and use the tax rates in other European countries as instruments. Devereux et al. (2008) outline a model in which multinational firms choose their capital stock based upon the effective marginal tax rate they face and simultaneously decide upon location of their profits in response to differences in statutory tax rates between countries. They find evidence that OECD countries compete over effective marginal tax rates for capital and over statutory rates for profit but that these effects are only present between open countries. Moreover, the reductions in equilibrium tax rates they observe can be explained almost entirely by more intense competition between countries due to the relaxation of capital controls. As in that paper we create an instrument using a distance weighted measure of the 24 OECD countries' corporate tax rates (excluding the country itself) and a simple average of the 11 European countries that make up the sample (excluding the country itself). [17] The instrument therefore varies across time and across countries, because of differences in the sample of countries used in each case and the use of distances to weight any changes that occur. We report the results from our preferred instrument, the weighted average measure, in regression 9 and the simple average in regression 10. So that we might conduct tests for overidentification, which are not

autonomous regions -0.014 (4.90) are all significantly related to the rate of firm productivity change. The coefficient (t-statistics) on the share of government expenditure expressed as a total of GDP is statistically significant and negative -0.013(16.96) as is government revenues -0.006 (9.57).

[17] The results are robust if we use distance weighted tax rates for other European countries; all OECD countries; or the average tax rates of neighbour countries as an instrument.

possible for perfectly identified models such as those in regressions 9 and 10, we also report the results from a regression where we include both instruments (regression 11).[18]

[Insert Table 8]

For this instrumental variable approach to be valid we require that the instruments are correlated with the endogenous variable, corporate tax rates, but not with firm-level productivity growth (other than through its effects on the endogenous variable). The diagnostic tests reported in the table indicate that the instruments appear relevant. An F-test on the excluded instruments indicates that they are strongly correlated with the TFP gap-tax interaction for small firms in regressions 9, 10 and 11 (the F-test on the instruments in the first stage regression range from 164 in regression 9 to 2600 in regression10).[19] The Sagan overidentification test in regression 11 also indicates that the assumption of instrument exogeneity is also satisfied (p-value = 0.46).

The coefficient on the tax variable is stable across the three IV regressions and statistically significant. In each case it is noticeably larger than those reported in Tables 5 and 7, which indicates a downward bias from omitted shocks. The coefficient is instead close to what we find when we include firm fixed effects in regression 14 (we discuss this regression further below).

Before moving to our final attempt to tackle the issue of endogeneity through the use of a natural experiment, we follow Arnold et al. (2011) and take an agnostic view on what the endogenous variable might be. In regressions 12, 13 and 14 we flood the regression with dummy variables. In regression 12 (Table 9) we control for the possibility that rate of convergence differs for each country-industry combination by interacting the TFP gap variable with a full set of country-industry dummies. In this regression we assume that the omitted variable is country-industry specific and affects the rate of convergence, but is time-invariant in nature. These cross-country and industry difference in the rate of convergence might occur because convergence is affected by other aspects of the policy environment. Arnold et al. (2008) find for example that product market regulations affect productivity catch-up. As there is now a convergence parameter for each country-industry combination we do not report the results for this variable in the table. In regression 13 we extend the specification to include a full set of country-time and industry-time effects.[20] The inclusion of the country-time dummies ensures that the effects of taxation are identified only through their

[18] In their study of tax competition Brett and Pinkse (2000) and Egger, Pfaffermayr, and Winner (2005a,b) use neighbours weighted GDP, population etc. as instruments. The results for the tax-TFP gap variable are robust to the use of these instruments, but we find that the overidentification test is not passed. For that reason we do not report these regressions.

[19] The coefficients on the instruments also have the expected signs. The coefficients (t-statistics) on the weighted average and simple average of the other countries tax rates are -0.141(17.51) and-0.631 (359.81) respectively. These indicate that when tax rates of a country are high relative to other European countries the direction of any change in tax rates is downward.

[20] We cannot use country-time dummies in conjunction with an instrumental variable approach because the instruments also vary by country and time and are thus perfectly collinear with the country-time effects in the first stage regression.

interaction with the productivity gap for small firms. This has the advantage that the coefficient on the corporate tax-TFP gap-size variable can be affected by endogeneity bias only if the omitted variable differs in its effects according to the size of the productivity gap of small firms. This would could also be used to indicate that parameter heterogeneity across countries are not a strong feature of our results. The likelihood that any omitted variable bias explains the results that we find is thus also reduced. The industry-time dummies capture factors such as differences in the underlying rate of growth of the global technical frontier, industry profitability or external financial dependence.

[Insert Table 9]

Allowance for either country-industry differences in the rate of productivity convergence or the inclusion of country-time and industry-time effects has no effect on the main conclusions of the paper. We continue to find evidence consistent with the view that high corporate tax rates slow convergence of small firms by reducing the returns to productivity enhancing investments.

Thus far we have assumed that the investments a firm makes in its productivity will move it closer to the domestic-industry frontier. As a final exercise in this section we relax this assumption and allow for the possibility that the returns to productivity enhancing investments may be constrained by difficult to observe firm specific characteristics such as the managerial ability of the firm (Bloom and Van Reenen, 2007, 2010). Deficiencies in management capabilities within a firm might mean that it is not capable of ever reaching the productivity of the best firms resulting in a permanent deficit in the steady state productivity level. In regression 14 we control for these time-invariant firm characteristics through the inclusion of firm fixed effects alongside the country-time and industry-time effects.

We continue to find that corporate taxation significantly slows productivity convergence when we control for firm fixed effects. As noted above, the magnitude of the coefficient is now similar to that found from the IV regressions. The effects of corporate taxation appear relatively strong in this regression, even for firms that are close to the productivity frontier. According to the results reported in regression 14, for a small firm with a productivity level 85% of the frontier firm and in a country with corporate tax rates of 25% compared to 20%, productivity growth is an estimated 1.95 percentage points lower. When the firm faces a corporate tax rate of 40% rather than 20%, productivity growth is an estimated 7.8 percentage points lower.

4.4 The 2001 Tax Change in Germany as a Natural Experiment

As noted in the summary statistics in Section 3, for most of the countries that make up our sample the rate of corporate taxation is reduced occasionally and in relatively small steps, such that it displays a general downward trend over the sample period. The exception to this is Germany where there was a large single reduction of just over 13 percentage points between 2000 and 2001. This was the only corporate tax change between 1999 and 2002 in Germany. The key features of the reforms were the replacement of the different tax rates on retained earnings (40%) and distributed profits (30%) with a single lower tax on all profits (25%). When combined with local trading taxes, the statutory tax rate fell from 51.6% to 38.3% (Spengel, 2001). Becker et al. (2006) use this tax change as a 'natural experiment' to identify the effects of tax reform on the investment of foreign affiliates in Germany, finding significant and large effects. Becker et al. (2006) describe the motives behind this tax reform as aimed at attracting FDI, encouraging investment and to adapt the German tax system to the rules of the EC Common Market. The motives behind the tax change therefore appear to be consistent with the view that the change in corporate tax rates was exogenous to firm productivity.

In the regressions in Table 10 we consider whether these reforms affected the productivity growth of small German firms using the change in the tax rate in 2001 to identify the effect of corporate taxation on productivity convergence. Using data only for Germany in regressions 15 to 17, the effect of corporate taxation is identified from differences in the effect of the change in the corporate tax rate between 2000 and 2001 for small firms with different productivity gaps relative to the domestic-industry productivity frontier. In all other time periods this variable has a value of zero.[21] As in previous regressions we also control for the initial TFP gap of a firm, and the interaction of this variable with a dummy for small firms. In regression 16 we test whether the tax change had any effect on productivity growth on all German firms, or whether it was specific to small firms. This regression might be thought of as a triple-difference regression. We anticipate that the effects of taxation affected small firms only. In regression 17 we also include firm fixed effects to control for unobservable time invariant time firm-specific factors, such that we now rely only on the within firm, cross-time information in the data to identify the effects of taxation.

The results reported in Table 10 are robust to the use of this natural experiment for corporate taxation in Germany; we continue to find strong evidence that the rate of convergence by small firms is slowed by corporate taxation or rather the change in corporate tax rates in this case. The decrease in German corporate tax rates increased the rate of productivity convergence, where the estimated effect is around half that reported in Table 8 when using an IV approach (regressions 9-

[21] Tax changes also occurred in a number of other years in Germany, although on a smaller scale. These are ignored in producing the results in regression 15 but the results we report in the Table are robust to the inclusion of these other tax changes.

11) or including firm fixed effects (regression 14) and about 3 times that when we include various country and industry dummy variables. Moreover, in regression 16 we find that the same tax change had no effect on the rate of productivity growth for large firms (given by the TFP gap*∆Corp.Tax variable) . For this group we find no evidence of TFP catch-up; both the TFP gap variable and the TFP gap variable interacted with corporate taxation are insignificantly different from zero. Again this supports the conclusions we drew earlier in the paper about the productivity effects of taxation on large firms. This might be viewed as consistent with the summary statistics in Table 3, where the average German firm was found to operate relatively close to the domestic-industry frontier. The inclusion of firm fixed effects in regression 17 does not affect the relationship between corporate taxation and productivity catch-up found elsewhere in the table but it does reduce the estimated magnitude of this effect. From this table we conclude there is strong evidence that the German tax reform of 2001 affected the productivity catch-up of small firms, and only small firms.

Using the 13 percentage point reduction in corporate tax rates and the coefficient estimates from regression 17 then our results suggest for a firm with a productivity gap 75% of the frontier firm implies TFP growth would have been 2.2 percentage points faster compared to a counterfactual of no-change in the corporate tax rate. The average TFP even of small firms tends to be higher than this in Germany, in which case the effects are somewhat smaller. For a small firm with a TFP level 85% (90%) of the frontier firm our estimates suggest that TFP growth increased by 1.2 (0.8) percentage point compared to that predicted if corporate tax rates were left at 51 per cent.

[Insert Table 10]

In the final regressions of Table 10 we consider the effect of the natural experiment in a different manner. Thus far we have used large German firms as the counterfactual group to that of small firms. If there was a European-wide shock to the productivity of small firms over this time period then large German firms do not provide an appropriate counterfactual, whereas small firms from other European countries would. In regressions 18 to 20 we consider the robustness of our results to the use of small firms from Spain, Sweden and the UK as a counterfactual. Firms from these countries are chosen because the corporate tax rates remained unchanged over the years 1999 to 2002, but would still be affected by any European-wide productivity shocks to small firms. In all other non-German countries in the sample the corporate tax rate changed across these years. Using the results from regressions 18-20 in conjunction with those in reported as regressions 15-17 rules out the possibility that German specific, or small firm specific events, which might include policy change or random shocks, explain the changes in productivity growth we find for small German firms following the 2001 tax reforms.

In regression 18 we include country-year dummies as before, but now interact the German tax event dummy (equal to 1 for Germany in 2001; zero otherwise) with the small firm TFP gap-corporate tax term.[22] Based on our earlier findings we anticipate that the coefficient on the TFP gap*D_{SIZE}*Corp.Tax variable is positive; higher corporate taxation slows productivity catch-up in small firms in Germany, Spain, Sweden and the UK, but that the 2001 tax reforms in Germany, given by the TFP gap*D_{SIZE}*Corp.Tax*D_{GERM01} variable has a negative effect. The tax change in Germany increased the rate of productivity convergence of small firms. We continue to find that high corporate tax rates reduce the rate of productivity growth within small firms in regression 18, as shown by the small firm's TFP gap-corporate tax interaction, but that the reduction in corporate tax rates led to significantly faster productivity growth within the treatment group, shown by the small firm TFP gap*corp tax*Germany 2001 variable. Moreover, our results are unchanged when we exclude small UK firms from the control group (regression 19) on the basis that UK corporate tax rates were reduced in 1998 and this may have affected subsequent productivity growth.[23]

Finally, Bertrand et al. (2004) note that many difference-in-difference studies use data spanning more than just a before and after period. A consequence of this is that where outcomes are serially correlated, standard errors will be inconsistent resulting in artificially small standard errors and spurious inference. One solution suggested by Bertrand et al. (2004) is to collapse the data into a single pre- and post-treatment group. We conduct this robustness test in regression 20 of Table 10. The pre-treatment period is defined as the years 1999 and 2000 while the post-treatment period is 2002. We therefore calculate the mean of each variable by firm-period and re-estimate the equation. In order that this is comparable with the results in regression 18 country-period and industry-period dummies are included in the model. Although the standard errors are somewhat larger when we use this approach relative to those reported in regression 18, our results remain robust and highly significant. In fact the coefficient on the treatment interaction (-0.6075) is almost identical to that found when the model is estimated using multiple years of data.

5. Conclusions

The role that government plays in encouraging increased productivity growth in firms has always attracted considerable academic interest. Much of this interest has however, been focused on those policy changes that foster changes in the extent of competition in an industry, either from foreign or other domestic firms. In this paper we consider a more basic aspect of the policy environment of a

[22] The German tax event dummy is, of course, perfectly collinear with the country-year dummies meaning that it is omitted from the regression.

[23] The results are in fact robust to all possible permutations of the control group.

country, the role of corporate taxation. That taxation might affect productivity is not new, but its effects have typically only been examined as indirect consequences of changes in the desire by firms to invest in physical capital or R&D. In this paper we instead provide evidence on whether it affects the returns to productivity enhancing investments, slowing the rate at which small firms catch-up with the best firms in their industry and country. We find evidence consistent with this view. Higher rates of corporate taxation slow the rate of convergence for small firms, who are likely to be the most constrained from making productivity enhancing investments. These results appear very robust to the addition of covariates to the regression, including those which account for differences in the steady state level of productivity of firms, or the rate of convergence by firms in the same industry-frontier. They are also robust to attempts to instrument for taxation using other OECD country tax rates, flooding the regression with various country, industry and firm dummy variables and using the 2001 tax reform in Germany as a natural experiment. The results are therefore consistent with a causal interpretation from corporate taxation on the rate of convergence and suggest heterogeneity in the effects of taxation across firms. Small firms are affected, whereas large firms are not, and firms with a large productivity gap are more affected than firms with a small productivity gap compared to the best firms in their country and industry.

Tables

Table 1: Number of Observations by Year

Year	**Observations**
1996	617
1997	837
1998	2,176
1999	15,497
2000	20,800
2001	23,556
2002	31,268
2003	44,124
2004	46,495
2005	41,098
Total	226,468

Table 2: Population Summary Statistics

	Observations	**Mean**	**Std. Dev.**
Firm productivity growth$_{ijct}$	226,468	2.7%	68.6
TFP growth of frontier$_{jct}$		1.0%	13.1
TFP gap with frontier firms$_{jct}$		0.789	18.4

Notes: TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*.

Table 3: TFP Gap with Frontier by Country

	All firms							
	Mean TFP gap (all firms)	**Mean TFP gap (Emp. <20)**	**p25**	**p50**	**p75**	**sd**	**Obs. (all firms)**	**Obs. (Emp. <20)**
Austria	0.743	0.339	0.646	0.988	0.999	0.356	98	96
Czech Republic	0.583	0.512	0.393	0.532	0.795	0.256	8,684	7,722
Denmark	0.610	0.489	0.432	0.625	0.811	0.252	1,021	946
Finland	0.814	0.794	0.750	0.808	0.879	0.101	5,305	4,175
France	0.664	0.598	0.602	0.667	0.737	0.135	8,299	6,208
Germany	0.892	0.831	0.843	0.994	0.999	0.173	22,857	12,663
Italy	0.772	0.781	0.654	0.788	0.923	0.180	88,016	68,264
Portugal	0.873	0.913	0.761	0.834	0.991	0.114	410	275
Spain	0.709	0.687	0.622	0.713	0.791	0.130	47,915	42,328
Sweden	0.683	0.646	0.594	0.682	0.775	0.145	11,698	11,430
United Kingdom	0.804	0.803	0.687	0.842	0.990	0.187	32,165	29,462
Total							226468	183569

Notes: TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*.

Table 4: Corporate Tax Rates and Changes

	Average Tax Rate (%)	**Change between 1995 and 2005 (change in percentage points)**
Austria	33.18	-9
Czech Republic	33.36	-15
Denmark	32.00	-6
Finland	28.00	1
France	37.14	-6.7
Germany	45.46	-18
Italy	43.27	-14.9
Portugal	35.00	-12.1
Spain	35.00	0
Sweden	28.00	0
United Kingdom	31.00	-3

Notes: Statutory corporate tax rates are from the Eurostat Taxation Trends in the EU. The years of tax reform are those that occur during the sample window of each country in Table 1. No tax reforms are found for Spain and Sweden during these time periods.

Table 5: Corporate Taxation and Productivity Convergence

Regression No.	1	2	3	4
Estimator	**OLS**	**OLS**	**OLS**	**OLS**
TFP growth of frontier$_{jct}$	0.335	0.347	0.347	0.347
	(57.36)**	(64.92)**	(63.78)**	(65.31)**
TFP gap	-0.235	-0.333	-0.338	-0.303
	(15.17)**	(15.51)**	(6.95)**	(19.23)**
[TFP gapD_{SIZE}]*Corp. Tax$_{ct}$*	-0.048	0.215	0.210	0.411
	(1.41)	(5.77)**	(4.30)**	(4.60)**
*TFP gap*Corporate Tax Rate$_{ct}$*			-0.019	
			(0.16)	
TFP gapD_{SIZE}*				-0.103
				(2.36)*
*TFP gap*Profitability$_j$*	-0.001	0.001	0.001	0.000
	(1.22)	(1.66)+	(1.90)+	(0.50)
[TFP gapD_{SIZE}]*Profitability$_j$*	-0.002	-0.001	-0.001	-0.000
	(5.09)**	(2.78)**	(2.11)*	(0.33)
Additional Control Variables				
Country dummies		√	√	√
Time dummies	√	√	√	√
Industry dummies		√	√	√
No. of firms	54,787	54,787	54,787	54,787
Observations	226,468	226,468	226,468	226,468

Notes: +, * and ** indicate significance at the 10%, 5% and 1% levels of significance. Standard errors are clustered at the firm level and reported in parentheses. TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*. The dependent variable is the rate of productivity growth in firm *i*. D_{SIZE} is a dummy equal to one for firms with less than 20 employees.

Table 6: Estimated Effects from Taxation on the Productivity Growth of Small Firms

	Corporate Tax Rate				
TFP gap (% of frontier)	**25%**	**30%**	**35%**	**40%**	**45%**
75%	-0.31	-0.62	-0.93	-1.24	-1.55
85%	-0.17	-0.35	-0.52	-0.70	-0.87
95%	-0.11	-0.23	-0.34	-0.45	-0.57

Notes: In this table we report how much slower firm productivity would be expected to grow relative to a firm that pays a 20% corporate tax rate and has the same TFP gap relative to the frontier.

Table 7: Corporate Taxation and Productivity Convergence

Regression No.	5	6	7	8
Estimator	**<50 emps**	**Small firm tax**	**Effective tax rates**	**OLS**
TFP growth of frontier$_{jct}$	0.345	0.349	0.374	0.328
	(65.82)**	(64.30)**	(86.65)**	(52.85)**
TFP gap	-0.321	-0.302	-0.300	-0.385
	(20.50)**	(19.05)**	(17.74)**	(26.62)**
[TFP gapD_{SIZE}]*Corp. Tax$_{ct}$*	0.295	0.395		0.454
	(12.71)**	(5.87)**		(5.04)**
[TFP gapD_{SIZE}]*Eff. Ave Tax$_{ct}$*			1.224	
			(6.27)**	
[TFP gapD_{SIZE}]*			1.511	
** Eff. Ave. - Marg. Tax*			(13.64)**	
TFP gapD_{SIZE}*	-0.047	-0.090	-0.374	-0.181
	(2.02)*	(2.78)**	(5.61)**	(4.52)**
*TFP gap*Profitability$_j$*	0.000	0.000	0.000	0.003
	(0.30)	(0.35)	(0.33)	(5.30)**
[TFP gapD_{SIZE}]*Profitability$_j$*	0.000	0.000	0.001	0.002
	(0.03)	(0.04)	(1.21)	(2.78)**
Additional Control Variables				
Country dummies	√	√	√	√
Time dummies	√	√	√	√
Industry dummies	√	√	√	√
Political controls$_{ct}$				√
Fiscal controls$_{ct}$				√
No. of firms	54,787	54,787	50,311	48,733
Observations	226,468	226,468	216,713	198,875

Notes: +, * and ** indicate significance at the 10%, 5% and 1% levels of significance. Standard errors are clustered at the firm level and reported in parentheses. TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*. The dependent variable is the rate of productivity growth in firm *i*. D_{SIZE} is a dummy equal to one for firms with less than 20 employees, except in column 1 where they are defined as having less than 50 employees.

Table 8: Corporate Taxation and Productivity Convergence: Testing for endogeneity bias

Regression No.	**9**	**10**	**11**
Estimator	**IV**	**IV**	**IV**
Instrument	**Weighted average of OECD country tax rates**	**Simple average of OECD country tax rates**	**Weighted average and simple average of OECD country tax rates**
TFP growth of frontier$_{jct}$	0.327	0.328	0.328
	(85.98)**	(85.72)**	(85.74)**
TFP gap	-0.369	-0.368	-0.368
	(55.67)**	(54.42)**	(54.38)**
[TFP gapD_{SIZE}]*Corp. Tax$_{ct}$*	2.078	2.225	2.156
	(10.06)**	(8.99)**	(8.45)**
[TFP gapD_{SIZE}]*	-0.736	-0.787	-0.763
	(10.41)*	(9.29)**	(8.74)**
*TFP gap*Profitability$_j$*	0.003	0.003	0.003
	(11.96)**	(11.93)**	(11.95)**
[TFP gapD_{SIZE}]*Profitability$_j$*	0.001	0.001	0.001
	(5.32)**	(5.14)**	(5.20)**
Additional Control Variables			
Country dummies	√	√	√
Time dummies	√	√	√
Industry dummies	√	√	√
Political controls$_{ct}$	√	√	√
Fiscal controls$_{ct}$	√	√	√
Instruments			
Weighted average of other OECD countries tax	√		√
Average tax rate of other European countries		√	√
F-test on excluded instruments	164	2600	1303
(p-value)	(0.00)	(0.00)	(0.00)
Sargan statistic (p-value)	-	-	0.546 (0.46)
No. of firms	48,733	48,733	48,733
Observations	198,875	198,875	198,875

Notes: +, * and ** indicate significance at the 10%, 5% and 1% levels of significance. Standard errors are clustered at the firm level and reported in parentheses. TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*. The dependent variable is the rate of productivity growth in firm *i*. D_{SIZE} is a dummy equal to one for firms with less than 20 employees.

Table 9: Corporate Taxation and Productivity Convergence: Testing for endogeneity bias

Regression No.	**12**	**13**	**14**
Estimator	**Country-Industry TFP gap**	**OLS**	**FE**
TFP growth of frontier$_{jct}$	0.334	0.318	0.616
	(52.31)**	(45.69)**	(83.50)**
TFP gap	-	-0.364	-1.008
	-	(25.17)**	(53.53)**
[TFP gapD_{SIZE}]*Corp. Tax$_{ct}$*	0.374	0.372	2.405
	(4.19)**	(4.01)**	(24.33)**
[TFP gapD_{SIZE}]*	-0.100	-0.173	-0.651
	(2.90)**	(4.23)**	(16.70)**
*TFP gap*Profitability$_j$*	-13.685	0.002	0.004
	(1.06)	(4.52)**	(5.09)**
[TFP gapD_{SIZE}]*Profitability$_j$*	-0.000	0.002	-0.004
	(0.65)	(3.63)**	(7.62)**
Additional Control Variables			
Country dummies	√	-	-
Time dummies	√	-	-
Industry dummies	√	-	-
Political controls$_{ct}$	√	√	√
Fiscal controls$_{ct}$	√	√	√
*Country-industry*TFP gap*	√		
Country-Time dummies		√	√
Industry-Time dummies		√	√
Firm effects			√
No. of firms	48,733	48,733	48,733
Observations	198,875	198,875	198,875

Notes: +, * and ** indicate significance at the 10%, 5% and 1% levels of significance. Standard errors are clustered at the firm level and reported in parentheses. TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*. The dependent variable is the rate of productivity growth in firm *i*. D_{SIZE} is a dummy equal to one for firms with less than 20 employees.

Table 10: Corporate Taxation and Productivity Convergence: Sub-Sample of German Firms

Regression No.	15	16	17	18	19	20
Treatment Group	**Small German firms**	**Small German firms**	**Small German firms**	**Small German firms**	**Small German firms**	**Small German firms**
Control Group	**Large German firms**	**Large German firms**	**Large German firms**	**Small ESP, SWE, UK firms**	**Small ESP & SWE firms**	**Small ESP, SWE, UK firms**
TFP growth of frontier$_{jct}$	0.202	0.200	0.504	0.9855	0.9626	1.0370
	(4.11)**	(4.09)**	(29.90)**	(404.53)**	(170.82)**	(76.03)**
TFP gap	0.037	0.031	-1.082			
	(0.76)	(0.63)	(10.98)**			
*TFP gap*Δ Corp. Tax*$_{ct}$		-0.167				
		(0.65)				
*[TFP gap*D*$_{SIZE}$*]*ΔCorp.Tax*$_{ct}$	0.922	1.082	0.585			
	(4.75)**	(3.39)**	(8.64)**			
*[TFP gap*D*$_{SIZE}$*] *Corp.Tax*$_{ct}$				3.1754	3.0672	3.1730
				(168.69)**	(91.89)**	(89.43)**
*[TFP gap*D*$_{SIZE}$*] *Corp. Tax*$_{ct}$**D*$_{GERM01}$				-0.6288	-0.4685	-0.6075
				(-19.70)**	(-15.37)**	(-14.51)**
*[TFP gap*D*$_{SIZE}$*]*	-0.360**	-0.355**	0.170	-1.0103	-1.0176	-1.1476
	(6.18)	(6.02)	(2.09)*	(-468.08)**	(-242.31)**	(-71.83)**
Additional Control Variables						
Country-year dummies				√	√	
Industry-year dummies	√	√	√	√	√	
Country-period dummies						√
Industry-period dummies						√
Fiscal controls$_{ct}$	√	√	√			
Firm fixed effects			√	√	√	√
No. of firms	6,852	6,852	6,852	15,516	10,524	
Observations	26,147	26,147	26,147	36,844	24,515	20,814

Notes: +, * and ** indicate significance at the 10%, 5% and 1% levels of significance. Standard errors are clustered at the firm level and reported in parentheses. TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*. The dependent variable is the rate of productivity growth in firm *i*. D_{SIZE} is a dummy equal to one for firms with less than 20 employees.

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