Corporate Taxation and Productivity Catch-Up: Evidence from European Firms*

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Abstract
In this paper, we explore whether higher corporate tax rates, because they lower the after-tax returns to productivity-enhancing investments, reduce the speed with which small firms converge to the productivity frontier. Using data for 11 European countries, we find evidence that their productivity catch-up is slower when the statutory corporate tax rates are higher. In contrast, we find that large firms are instead affected by effective marginal rates. Using the reduced-form model of productivity convergence of Griffith et al. (2009, Journal of Regional Science 49, 689–720), our results are robust to a host of robustness checks and a natural experiment that exploits the 2001 German tax reforms.

Keywords: Convergence; firms; productivity; taxation

JEL classification: D24; H25; L11; O31

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I. Introduction

The large differences in the level of productivity that exist between firms within the same industry have stimulated what is now a significant body of research into the drivers of productivity change, and in particular the factors that encourage firms to catch up with those on the productivity frontier. Common themes within this research have included whether non-frontier firms invest to improve their productivity either in response to the presence of foreign multinational firms (see Görg and Greenaway, 2004, for a review), or in response to intra-market (Foster et al., 2001) and import competition (Nicoletti and Scarpetta, 2005; Schmitz, 2005). We contribute to this body of literature by testing whether aspects of the domestic policy environment affect the productivity catch-up of firms.

Whilst convergence of productivity levels from below is a feature present in our cross-country firm-level data, and has been found in other micro datasets by Bartelsman et al. (2008), Griffith et al. (2009), and others, there is also evidence that the rate of catch-up differs significantly across firms. This suggests the presence of features of the economic environment that constrain the ability of some firms to make productivity-enhancing investments (PEIs). In this paper, we investigate the role played by corporate taxation. The question we consider is therefore the following. Does higher corporate taxation reduce the expected returns to PEIs, diminishing the *ex ante* incentive for firms to invest, and thereby slowing their rate of productivity convergence?¹

In his summary of the firm productivity literature, Syverson (2011) has argued that differences in productivity across firms arise from differences in the creation of new technologies through R&D, as well as the quality of human and physical capital inputs, but also from “soft technologies” such as management and organization (Bloom and Van Reenen, 2007; Bloom et al., 2014). Traditionally, research on the effects of taxation at the micro level has concentrated on its effects on firms’ R&D and tangible capital investments. The relationship between tax policy (mostly R&D tax credits) and the volume, or the location, of R&D across countries/US states is reviewed in Hall and van Reenen (2000), while Auerbach (2002), Hasse and Hubbard (2002), and Hines (2005) examine the relationship between taxation and capital investment. The conclusion from this body of literature has been that high statutory corporate tax rates reduce investment in physical capital by increasing the user cost of capital (Hasset and Hubbard, ¹This builds on the idea, known since Arrow (1962), that restrictions on the ability to appropriate the returns to innovations slow the rate of technological progress. }
Where new vintages of physical capital embody technological progress, this will reduce firm-level productivity and slow convergence.

The effect of changes to management practices and firm organizations on productivity opens the possibility that the effects of taxation on productivity are stronger than would be suggested by this existing body of literature on tangible capital investment and R&D. Additionally, the effects of taxation on productivity might be affected by different measures of the corporate tax regime. For example, the measures of forward-looking effective marginal tax rates constructed by Devereux and Griffith (2003) are applicable to an investment in plant and machinery, undertaken under alternative assumptions regarding the relevant rate of interest, inflation rate, and method of financing (debt, equity), and which account for various depreciation allowances for different types of capital investment provided under the tax code. In contrast, changes to the way that a firm is managed usually involve an investment of managerial time to identify, organize, and implement changes, and do not qualify for tax credits or depreciation allowances. For investments of this type, the possibility is raised that the statutory corporate tax rate is the most empirically relevant measure of taxation. Further motivation for this view comes from Lee and Gordon (2005), Arnold et al. (2011), and Gemmell et al. (2011) who produce evidence that macro-level measures of total factor productivity (TFP) are affected by tax variables including the statutory corporate tax rate. Gemmell et al. (2015) show that the statutory rate has a stronger and more robust effect on growth than the Devereux and Griffith (2003) measures of taxation.

Economic theory also motivates a search for evidence that corporate taxes elicit heterogeneous productivity responses. Again drawing on the capital investment literature, Egger et al. (2014) develop a tractable model of corporate taxes and firm-level investment. Depending on their size, firms respond in different ways to different forms of taxation. Small (innovative) firms are credit-constrained, which makes investment sensitive to cash flow and the amount of collateral they can post. Because small firms rely heavily on retained profit for investment, higher tax rates reduce internal funds and lower the levels of investment.

Our conclusions regarding the effects of corporate taxation on the productivity convergence of small firms are reached by undertaking two complementary pieces of empirical analysis. First, we exploit variation in

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2 Further detail on the user cost of capital is provided for the interested reader in Online Appendix D.

3 See Beck et al. (2008) for evidence that small firms are more likely to be credit-constrained than large firms. Hubbard (1998) and Aghion et al. (2007) show that firm growth is limited by financial frictions.
the tax rates faced by firms in different countries over time. Using the reduced-form model of firm productivity convergence by Griffith et al. (2009), and an unbalanced panel of manufacturing and service sector firms from 11 European countries over the period 1996–2005, we find that higher statutory corporate taxation significantly slows the productivity growth of small firms that are furthest from the productivity frontier. In contrast, we show that these effects do not apply to large firms, even those with a greater scope for imitation. However, we do find some evidence that these large firms are affected by higher effective marginal tax rates, whereas small firms are unaffected, and there is an effect from personal income taxation on both types of firms. This final result is consistent with the view that the productivity investments of firms are dependent on the actions of workers though management and organizational change. Together, these results highlight an important heterogeneity in the effects of taxation across countries, and additionally across firms within the same country according to the size of their productivity gap relative to the productivity frontier. In turn, this implies that the effects of changes to taxation on aggregate productivity growth will depend upon the level of taxation, the structure of taxes, the numbers of small firms, and the average productivity gap.

The second component of the empirical evidence we provide exploits a quasi-natural experiment in which there was a 13 percentage point reduction in corporate tax rates in Germany between 2000 and 2001. The reform is plausibly exogenous with respect to firm productivity as it was designed to adapt the German tax system to the European Community (EC) Common Market (Becker et al., 2006). We again find evidence consistent with the view that higher tax rates slow productivity convergence for small firms. Following the reduction in corporate tax rates, productivity growth in small German firms increased compared to a counterfactual of small firms in those European countries where there was no tax change over this period (Sweden, Spain, and the UK). These effects are economically significant. Our results suggest that the effect of the reduction in the corporate tax rates in Germany was to raise the productivity growth rate for a small firm with the mean level of productivity (83 percent of the frontier firm) by 1.7 percentage points relative to the counterfactual.

Importantly, our econometric tests take several steps to isolate causal inferences. In our setting, endogeneity bias might arise as a result of omitted variable bias or of reverse causality if there is little deadweight loss from taxing firms that persistently lie far from the productivity frontier.

\[4\] In this regard, the paper complements evidence of an effect from 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).
To eliminate these potential sources of bias, our cross-country approach includes country, industry, and year dummies, and our robustness test includes country–time and industry–time dummies, which net out any time-varying shocks that systematically correlate with changes to tax rates. Furthermore, we use the natural experiment to drive at causality.

As discussed in the next section, the evidence we provide is consistent with that presented by Arnold et al. (2011) and Masso et al. (2013). Arnold et al. (2011) find evidence that, for European firms, higher corporate taxes slow productivity growth in more profitable industries. Masso et al. (2013) find that, for Estonian firms, corporate tax cuts provoke a significant increase in investment spending, with the effect most pronounced among small firms.

In the following section, we outline the previous body of literature and the econometric model that we adopt to estimate the effects of corporate taxation. In Section III, we describe key characteristics of the data. In Section IV, we detail the main results of the paper. This includes the baseline estimates, various tests of their robustness, and the effect of the German tax reforms. Finally, we draw some conclusions in Section V.

II. Previous Literature and Econometric Strategy

Previous Literature

Macro-dynamic modelling has made great strides in recent years in analysing the potential impact of changes in tax policy on a variety of macro variables including output levels and the transitional/long-run rates of output growth (e.g., Barro et al., 1995; Turnovsky, 2004). While some of these models have been tested by calibrating them to the characteristics of a specific country (usually the US), in general empirical tests of such models have relied on aggregate level regressions for panels of different country samples (e.g., Kneller et al., 1999; Bleaney et al., 2001). These studies have increasingly found evidence consistent with significant adverse long-run impacts from increases in various distortionary taxes including corporate tax rates. Theories of taxation and growth by Peretto (2007), and empirical studies by Lee and Gordon (2005), Arnold et al. (2011), and Gemmell et al. (2011, 2015) have also shown that these aggregate growth effects occur through productivity, in addition to any effect on the accumulation of tangible and human capital.

Aggregate productivity growth occurs as a consequence of the replacement of low-productivity firms by new entrants with higher productivity (in a process often called Schumpeterian “creative destruction”), as a consequence of the reallocation of resources to high-productivity firms (known as the between effect), and as a consequence
of the improvement in the productivity of surviving firms (known as the within effect). The research linking these aggregate productivity and growth effects of taxation to changes at the micro-level has concentrated on a small number of potential mechanisms. In this paper, we focus on the effects of taxation on within-firm productivity change. Recent evidence for firm-level effects of taxation has focused more on firm entry and exit rates (see Djankov et al., 2010; Da Rin et al., 2011), while Carroll et al. (2000) have examined the effects of US tax reforms in the 1980s on the investment and employment decisions of small businesses, and have found significant effects.

Syverson (2011) provides a detailed discussion of the determinants of within-firm productivity change, including that on the quality of inputs (both human and physical capital), on the creation of new technologies through R&D, and more recently on management quality and managerial change (Bloom and Van Reenen, 2007, 2010). As already discussed, research on the effects of taxation has concentrated on the direct effects of R&D and capital investments.

Empirical evidence of a direct relationship between taxation and firm productivity is more limited, with evidence currently confined to Arnold et al. (2011) and Masso et al. (2013). The regression-based approach adopted by Arnold et al. (2011) and Masso et al. (2013) is most similar to the work in this paper. Arnold et al. (2011) use a large sample of European firms, and they report that firms in industries that are more profitable are more affected by corporate taxation. Masso et al. (2013) use a significant change to corporate profit taxation in Estonia at the start of the century as a natural experiment. They find that compared to a counterfactual of firms in Latvia and Lithuania, the productivity and investment behaviour of small firms were particularly affected by changes to profit taxation that occurred.

Econometric Strategy

We take two complementary approaches to explore the link between productivity catch-up and corporate taxation. To capture the various effects of taxation on the productivity growth of firms using cross-country data, our first approach draws on Griffith et al. (2009) and estimates a reduced-form model with an error correction structure set out in equation (1), where $A$ denotes productivity, $i$, $j$, and $c$ denote firms, industries, and countries, respectively, $F$ is the frontier, and $t$ is time:

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5 The database from which we draw our information on firms, Amadeus, provides incomplete information on the entry and exit process. This prevents us from additionally exploring this channel using these data.
\[ \Delta \ln A_{ijct} = \alpha_0 + \alpha_1 \Delta \ln A_{Fjct} + \alpha_2 \ln \left( \frac{A_{ijct-1}}{A_{Fjct-1}} \right) + \alpha_3 \ln \left( \frac{A_{ijct-1}}{A_{Fjct-1}} \right) T_{ct} + \alpha_4 \ln \left( \frac{A_{ijct-1}}{A_{Fjct-1}} \right) \times Z_j + \alpha_5 T_{ct} + \alpha_6 X_{ijct} + \gamma_c + \gamma_j + \gamma_t + \epsilon_{ijct}. \] (1)

The parameter \( \alpha_1 \) in equation (1) captures the instantaneous effect of changes in the productivity frontier (denoted \( \Delta A_F \)) on all firms, and \( \alpha_2 \) captures the speed at which firms can close the gap with the best firms. We anticipate that \( \alpha_2 \) will be negative: the greater the size of the initial productivity gap of firm \( i \) relative to the frontier in the previous time period, the faster a firm grows in this time period. Following evidence from Bartelsman et al. (2008), we assume in equation (1) that firms benchmark themselves against the productivity level of the domestic leader in their industry. The country–industry frontier is considered the relevant benchmark because of differences in the appropriateness of different management practices to different country and industry settings.6

We allow taxation to affect productivity growth directly (captured by \( \alpha_5 \)), because it affects the decision to invest in the creation of new knowledge such as R&D, but also the catch-up process (captured by \( \alpha_3 \)). It is the effect on the rate of catch-up where we concentrate our analysis. We anticipate that these constrained and highly taxed firms will make fewer, smaller, and less risky investments to improve their productivity (Arnold et al., 2011), so that the speed of convergence to the frontier will be slower. In this case, the coefficient \( \alpha_3 \) will be positive. Alternatively, if higher taxation encourages firms to work harder to improve productivity, then \( \alpha_3 \) will be negative. In our empirical work, we focus on incorporated firms so that it is the effect of corporate tax rates that is most relevant. We consider possible effects from personal income taxes later in Section IV.

Given the broad range of determinants of productivity and the predictions in Egger et al. (2014), in our initial investigations we use a basic measure of corporate taxation (i.e., the statutory tax rate). In Section IV, we explore the potential for broader measures, including measures of the effective tax

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6Bartelsman et al. (2008) find that firms converge more quickly to the domestic-industry frontier than the global-industry frontier. This assumption has the convenient property that conversion to a common currency is not required; such transformations are known to be sensitive to assumptions about the choice of exchange rate (Bartelsman et al., 2008). The exclusion of the global frontier is, arguably, most plausible for small firms. We test the robustness of our results to this assumption by including, in regression 9, industry–time dummies that capture movements of the global-industry frontier.

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rate based on investments in plant and machinery. Finally, motivated by evidence in Egger et al. (2014) that the effects of taxation are likely to differ across firms of different sizes, we focus our analysis on small firms. We also test the sensitivity of our results to the definition of smallness.

We also include a number of other control variables within equation (1), although limits on space prevent us from reporting all of these within the tables. In equation (1), we include a set of interactions between the TFP gap and industry profitability, which we denote by $Z_j$. This captures the fact that the speed of convergence can depend on industry profitability (Arnold et al., 2011). Here, we hypothesize that greater profitability might act as a spur to make PEIs. 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 we use (time-invariant) industry-level data on profitability for the US as a proxy.7

To control for other factors that affect productivity but are not accounted for in the above model, we include a set of variables denoted by $X_{ijct}$ in equation (1). Within this we include the ratio of government expenditure to GDP and the ratio of government revenue to GDP. Finally, we also include a set of country, industry, and time dummies. To further establish the robustness of our findings later in Section IV, we extend the set of control variables to include country–time and industry–time dummies, and then firm fixed effects.

The second approach we use to identify the effects of taxation on productivity convergence is to exploit for identification purposes a large change in the German corporate tax rate between 2000 and 2001. These productivity growth effects are compared to a counterfactual of firms from Spain, Sweden, and the UK, where there were no changes to corporate tax rates over the years 1999–2002. The high degree of synchronization in business cycles across European countries, reported by Afonso and Sequeira (2010), Degiannakis et al. (2014), and Gayer (2007), ensures that economic conditions within the treatment and control groups are similar, and it further supports this choice.

7 We derive this variable using US data as US firms are subject to lower tax rates and fewer policy restrictions compared to those in Europe. Also, US data are not included in the sample, thereby reducing endogeneity concerns. Information on the profitability of industries is calculated from the 2002 US Benchmark Input–Output Data Table. For each two-digit ISIC industry, a profitability ratio is calculated as gross operating surplus divided by value added, and it is then applied to the 1995–2005 period. As $Z_j$ is time-invariant, any direct effects of this variable are captured by the industry fixed effects. In regression C7 in the Online Appendix, we replace this with a measure derived from the Amadeus dataset (summary statistics are in Table B1 in the Online Appendix). This choice has no bearing on our conclusions for taxation.
The estimating equation used in this section is laid out as equation (2) and takes on the form of a difference-in-differences regression:

$$
\Delta \ln A_{ijct} = \beta_1 \Delta \ln A_{Fjct} + \beta_2 \ln \left( \frac{A_{ijct-1}}{A_{Fjct-1}} \right) + \beta_3 \ln \left( \frac{A_{ijct-1}}{A_{Fjct-1}} \right) \times \Delta T_{ct} + \beta_4 \ln \left( \frac{A_{ijct-1}}{A_{Fjct-1}} \right) T_{c,1999} + \beta_5 \ln \left( \frac{A_{ijct-1}}{A_{Fjct-1}} \right) \times Z_j + \beta_6 X_{ijct} + \gamma_i + \gamma_t + \varepsilon_{ijct}.
$$

Equation (2) retains much of the structure of equation (1) despite the change in identification strategy. The parameter $\beta_1$ captures the instantaneous effect of changes in the productivity frontier on all firms, and $\beta_2$ captures the speed at which firms can close the gap with the best firms. However, some changes to the tax variable are necessary. The tax variable now appears in two places in equation (2). The coefficient $\beta_3$ captures the effect of changes in taxation for small German firms, and it is therefore the main variable of interest in this regression. To capture the effect of differences in tax rates across countries before the 2001 German tax changes, we also include the interaction between the TFP gap and tax rates fixed at their pre-reform values (the value in 1999). The coefficient $\beta_4$ captures what would have happened to productivity growth if Germany had left its corporate tax rates unchanged. We anticipate that the signs on both of these variables are positive. The remaining control variables are chosen to be consistent with equation (1), except that we follow standard practice in the estimation of difference-in-differences regressions and include firm fixed effects.8

Our research design employs multiple strategies to pin down a causal relationship between tax policy and productivity convergence. First, we estimate equation (1) using country, industry, and year fixed effects that eliminate the confounding influence of omitted variables that are unobservable to the econometrician but correlate with tax policy. Secondly, the German natural experiment exploits an exogenous shock to tax policy, and it leverages the fact that this affected small German firms but not those in the control group.

III. Data Description and Summary

Our firm-level data are taken from the Amadeus database (Bureau van Dijk) and they cover 11 European countries for the years 1995–2005. We provide greater detail on the construction of the dataset and measures of

8 The firm fixed effects are perfectly collinear with country and industry dummies from equation (1), and so we do not include these. We continue to include time effects in this equation.
TFP in Online Appendix A, providing only a brief description here. As in Arnold et al. (2011), we restrict the analysis to firms in manufacturing and service sectors (NACE 15–93), and we exclude firms with missing data and obvious key punch errors. 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.

To construct measures of productivity, we estimate a separate production function for each country–industry pair, 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. The productivity frontier in each country–industry time period is approximated by the productivity of firms that lie above the 95th percentile of the TFP distribution. The 95th percentile, rather than the maximum value of TFP, is chosen to represent the frontier in order to reduce the possibility that extreme data points caused by measurement error will affect the results. The lagged TFP gap for each firm in each year is then constructed as the (log) of the ratio of the level of TFP of each firm to the relevant country–industry productivity frontier. As a consequence of measuring the lagged TFP gap, we require at least two observations for each firm, and therefore the data period for estimations covers the period 1996–2005. In order to concentrate on the determinants of productivity catch-up, we further restrict the analysis to non-frontier firms. This sample covers over 226,000 observations on 54,787 firms.

The country coverage differs, depending upon data availability within the Amadeus database. The larger European countries are particularly well represented. There are around 88,000 observations for Italy, 8,000 observations for France, 23,000 for Germany, 48,000 for Spain, and 32,000 for the UK. Therefore, around 88 percent of all observations are from these five countries. The panel dimension of the data is relatively short and is unbalanced across time. The loss of firm information is greater the further we move away from the base year of 2003 (see Online Appendix A for more details). There are over 40,000 observations in each of the years 2003, 2004, and 2005, but fewer than 1,000 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.

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9 We follow Griffith et al. (2009) in using Levinsohn and Petrin (2003) as the benchmark TFP estimation, and we use Olley and Pakes (1996) to test for robustness.

10 In regression C1 in the Online Appendix, we include frontier firms in the sample. As in the rest of the paper, the frontier is defined at the country–industry level. The results are robust to this change.
Corporate taxation and productivity catch-up

Table 1. Number of observations by year

|       | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Total  |
|-------|------|------|------|------|------|------|------|------|------|------|--------|
| Obs.  | 617  | 837  | 15,497 | 20,800 | 23,556 | 44,124 | 46,495 | 41,098 | 226,468 |

Table 2. Population summary statistics

|                                | Observations | Mean   | Std dev. |
|--------------------------------|--------------|--------|----------|
| Firm productivity growth\(_{ijct}\) | 226,468      | 0.027  | 0.180    |
| TFP growth of frontier\(_{jct}\)   |              | 0.006  | 0.108    |
| TFP relative to frontier firms\(_{jct}\) |            | 0.789  | 0.300    |

Notes: The TFP gap is measured as the ratio of firm \(i\)'s productivity to the frontier in industry \(j\), country \(c\), in time period \(t\).

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. We provide summary statistics on all of the variables included in the estimations in Online Appendix B. In Table 2, to ease the interpretation of the data, we report the TFP of the average firm expressed as a percentage of the productivity frontier rather than the logged value that we use in the estimation.

The average rate of TFP growth in the sample is 2.7 percent per annum. This is faster than the growth rate of the productivity frontier (an average rate of growth 0.6 percent per annum), which suggests that the average firm converges towards the frontier over time. Finally, across the sample, the average TFP of a firm compared to its domestic-industry productivity frontier is 79 percent. To put this differently, the TFP gap of the average firm compared to the productivity frontier is 21 percent.

In Table 3, we provide the distribution of relative TFP by country, the separate mean values for small and large firms, as well as further detail on the distribution of TFP.\(^{11}\) The evidence from this table suggests that 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 firms in France or the UK.\(^{12}\) The average firm in Germany has an estimated TFP that is 88 percent of the best firms there, whereas for France the average firm has a TFP that is 61 percent of the best firms. For the UK, the figure is 79 percent. The

\(^{11}\) Small firms are defined as those with fewer than 20 employees, measured in that year. In regression C2 in the Online Appendix, we fix firm size over the sample period. This has no bearing on the results. We choose 20 employees in order to maintain a reasonable number of observations in both groups. The robustness of this is tested in Section IV.

\(^{12}\) 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.
### Table 3. TFP relative to frontier firms by country

| Country             | Mean TFP All firms | Mean TFP Small firms | Mean TFP Large firms | Distribution of TFP p25 | Distribution of TFP p50 | Distribution of TFP p75 | TFP SD | Observations All firms | Observations Small firms |
|---------------------|--------------------|----------------------|----------------------|------------------------|-------------------------|-------------------------|--------|------------------------|-------------------------|
| Austria             | 0.346              | 0.339                | 0.933                | 0.109                  | 0.646                   | 0.988                   | 1.330657 | 98                     | 96                      |
| Czech Republic      | 0.514              | 0.512                | 0.525                | 0.393                  | 0.532                   | 0.795                   | 0.514886 | 8,684                  | 7,722                   |
| Denmark             | 0.499              | 0.489                | 0.636                | 0.432                  | 0.625                   | 0.811                   | 0.569424 | 1,021                  | 946                     |
| Finland             | 0.799              | 0.794                | 0.817                | 0.750                  | 0.808                   | 0.879                   | 0.135124 | 5,305                  | 4,175                   |
| France              | 0.606              | 0.598                | 0.630                | 0.602                  | 0.667                   | 0.737                   | 0.246946 | 8,299                  | 6,208                   |
| Germany             | 0.879              | 0.831                | 0.942                | 0.843                  | 0.994                   | 0.999                   | 0.237642 | 22,857                 | 12,663                  |
| Italy               | 0.757              | 0.781                | 0.681                | 0.654                  | 0.788                   | 0.923                   | 0.272344 | 88,016                 | 68,264                  |
| Portugal            | 0.897              | 0.913                | 0.863                | 0.761                  | 0.834                   | 0.991                   | 0.172882 | 410                    | 275                     |
| Spain               | 0.691              | 0.687                | 0.724                | 0.622                  | 0.713                   | 0.791                   | 0.210396 | 47,915                 | 42,328                  |
| Sweden              | 0.650              | 0.646                | 0.818                | 0.594                  | 0.682                   | 0.775                   | 0.281347 | 11,698                 | 11,430                  |
| UK                  | 0.790              | 0.783                | 0.872                | 0.687                  | 0.842                   | 0.990                   | 0.310001 | 32,165                 | 29,462                  |
| Total               |                    |                     |                     |                        |                         |                         |        | 226,468                | 183,569                 |

Notes: See note to Table 2 for an explanation of the TFP gap. “Small firms” refers to firms with fewer than 20 employees.

The average TFP of small firms is below that of large firms in every country except Italy and Portugal. In some cases, the difference between the TFP for small firms and the average across all firms is large. In Germany, for example, the average TFP of large firms compared to the frontier firm is 94 percent, versus 83 percent for small firms.

Table 3 also provides information on the dispersion of TFP in each country. It would appear from the table that France, Italy, and the UK have a longer tail to their distributions compared to Germany. The firm at the 25th percentile of the distribution has a TFP level that is 85 percent of the most productive firms in Germany, whereas in France it is 60 percent, in Italy 65 percent, and in the UK 69 percent. According to Table 3, the weakest performance occurs in Austria, the Czech Republic, and Denmark, although these are also amongst the countries for which we have least information. Here, the TFP of the average firm compared to the productivity frontier in these countries is 35, 51, and 50 percent, respectively.

We use the statutory corporate tax rate as our main measure of taxation, which we obtain from Eurostat, *Taxation Trends in the European Union*. In Section IV, we test the robustness of the results for this variable to the use of the effective marginal tax rate for an investment in plant and machinery.

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13 In regressions C4 and C5 in Table C1 in the Appendix, we consider the robustness to the exclusion of countries with very few observations. Regression C4 excludes the Czech Republic, and C5 also excludes Austria, Denmark, and Portugal.
Table 4. Corporate tax rates and changes

|      | (1)   | (2)   | (3)   | (4)   | (5)   | (6)   |
|------|-------|-------|-------|-------|-------|-------|
| Austria | 33.18 | −9.0  | 50.00 | 0.00  | 17.73 | −4.73 |
| Czech Republic | 33.36 | −15.0 | −     | −     | 14.62 | −4.68 |
| Denmark | 32.00 | −6.0  | 42.39 | −37.00| 19.91 | −3.44 |
| Finland | 28.00 | 1.0   | 36.82 | −5.50 | 18.46 | 2.23  |
| France | 37.14 | −6.7  | 50.64 | −8.80 | 18.94 | −0.59 |
| Germany | 45.46 | −18.0 | 49.86 | −11.00| 24.73 | −10.70|
| Italy | 43.27 | −14.9 | 47.36 | −5.00 | 17.57 | −8.60 |
| Portugal | 35.00 | −12.1 | 40.00 | 0.00  | 15.14 | −6.99 |
| Spain | 35.00 | 0.0   | 42.09 | −27.00| 20.48 | −2.39 |
| Sweden | 28.00 | 0.0   | 27.45 | −5.00 | 16.79 | 1.49  |
| UK | 31.00 | −3.0  | 40.00 | 0.00  | 20.77 | −2.36 |

Notes: The statutory corporate tax rate in percent (Column 1) and the top personal income rate in percent (Column 3) are from the Eurostat Taxation Trends in the European Union. The effective marginal tax rate in percent (Column 5) is from the Centre for Business Taxation at the University of Oxford. The reported tax rates are averages for the period 1995–2005. Columns 2, 4, and 6 show the change in each tax rate for 1995–2005 (in percentage points). No data on personal income taxes were available for the Czech Republic. Data on effective marginal tax rates were available for the Czech Republic for the years 2002–2005 and for Spain from 1996 to 2005 (the average and the change in taxation are measured across those years only).

(which we obtain from the Centre for Business Taxation at the University of Oxford) and the top marginal personal income tax rate from Eurostat, Taxation Trends in the European Union. The effective rates are hypothetical forward-looking marginal rates applicable to specified investment in plant and machinery undertaken under alternative assumptions regarding, for example, the relevant rate of interest, inflation and method of financing (debt, equity). They also account for various depreciation allowances for different types of capital investment provided under the tax code for each country. These are available for each year for all of the countries in our sample although only for the years 2002–2005 for the Czech Republic and 1996–2005 for Spain.

In Table 4, we report the statutory corporate, personal income, and effective marginal tax rate for each country averaged between 1995 and 2005. According to the information presented in the table, the highest average corporate tax rates are in Germany (45.5 percent) and Italy (43.3 percent). The corporate tax rates in the remaining countries range between 28 percent (Sweden, Finland) and 37 percent (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 percentage points), and Austria (9 percentage points). In contrast, in Spain and Sweden, the tax rate in 2005 was the same as in 1995, and in Finland it was 1 percentage

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point higher. Of the countries for which we have most data, the yearly changes in the rate of corporate taxation are generally relatively modest, of the order of 2–4 percentage points. An exception is Germany where the rate was reduced by 13 percentage points to 38 percent between 2000 and 2001. We focus on the effects of the tax reform in Germany as a test of the robustness of our findings at the end of Section IV.

Significant changes across time are evident for the other measures of taxation reported in Table 4. The top personal income tax rate fell by 37 percentage points between 1995 and 2005 in Denmark, and there were other large changes in France, Germany, and Spain. A comparison of the statutory corporate tax rate with the effective marginal rate indicates much smaller cross-country variation in the latter, owing to differences in the investment allowances that can be used to offset taxation in many countries. The cross-time changes in the effective marginal tax rate on investments in plant and machinery have typically been smaller than those for the statutory rate, and there are also some differences in their timing. The correlation between these two tax measures is 0.576, indicating that they might be capable of capturing quite different variation within the data.

## IV. Empirical Evidence

In this section, we report the results from the estimation of equation (1) and we provide a discussion of the magnitude of the estimated effects. Some general issues of robustness are explored and the effects of alternative tax variables are also considered. The effects of the 2001 tax reform in Germany can be found at the end of Section IV. As a reminder, in all of the regressions we include control variables for the general level of government expenditures and tax revenues alongside differences in the rate of convergence due to industry profitability. In the estimation of equation (1), we also control for country, industry, and time effects, except when we report regression 9, where we replace these with country–time and industry–time effects, and regression 10, where we include firm fixed effects. To conserve space, we report only the main variables of interest and we indicate in the table which other variables have been included.

### Baseline Estimates

The baseline estimates include regressions 1–3 in Table 5. In regression 1, we use the full sample of firms available to us. Regression 2 includes observations for small firms only (fewer than 20 employees) and regression 3 reports the same regression but where the sample is restricted to large firms (20 or more employees). Before we discuss the effect that these
### Table 5. Corporate taxation and productivity convergence

| Regression number | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  |
|-------------------|----|----|----|----|----|----|----|----|
| $\text{TFP growth of frontier}_{jct}(x_1)$ | 0.343*** | 0.356*** | 0.280*** | 0.366*** | 0.348*** | 0.344*** | 0.116*** | 0.188*** |
| (0.005) | (0.006) | (0.008) | (0.006) | (0.006) | (0.006) | (0.002) | (0.007) |
| $\text{TFP gap}(x_2)$ | −0.417*** | −0.434*** | −0.371*** | −0.504*** | −0.435*** | −0.427*** | −0.211** | −1.804*** |
| (0.046) | (0.053) | (0.062) | (0.057) | (0.052) | (0.051) | (0.091) | (0.331) |
| $\text{TFP gap} \times \text{CTax}_{ct}(x_3)$ | 0.368*** | 0.442*** | 0.069 | 0.640*** | 0.444*** | 0.436*** | 2.817*** | 2.040* |
| (0.090) | (0.101) | (0.164) | (0.107) | (0.100) | (0.099) | (0.296) | (1.161) |

Additional control variables
- ✓✓✓✓✓✓ ✓ ✓
- Fiscal and profitability variables
- ✓✓✓✓✓✓ ✓ ✓
- ✓✓✓✓✓✓ ✓ ✓

Observations
- 226,468
- 183,569
- 42,899
- 161,824
- 187,648
- 192,375
- 72,132
- 37,625

Notes: The regressions are: 1, all firms; 2, small firms; 3, large firms; 4, employees <10; 5, employees <30; 6, employees <50; 7, Olley–Pakes TFP; 8, Wooldridge TFP. *, **, and *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively. Standard errors are clustered at the firm level and are reported in parentheses. The dependent variable is the rate of productivity growth in firm $i$ in time period $t$. The TFP gap is measured as the logged ratio of productivity of firm $i$ over the productivity frontier in industry $j$, country $c$ in time period $t$. All regressions include industry profitability interacted with TFP gap, total government expenditure as a ratio to GDP, total government revenues as a ratio to GDP, the corporate tax rate, country, industry, and time dummies.
changes to the sample have on the tax variable, we begin with a discussion of results for the other control variables reported in the table.

The first two variables listed in the table measure the effect of growth of the technological frontier and the rate of productivity catch-up (denoted the TFP gap). The results for these compare favourably with those from elsewhere in the literature. First, growth of the domestic-industry productivity frontier is found to have positive spillover effects on the growth of firms operating behind the frontier; see Griffith et al. (2003) for similar evidence. The magnitude of the coefficient indicates that when the frontier grows by 1 percent, productivity in non-frontier firms grows by 0.343 percentage points. A comparison across regressions 2 and 3 suggests that the effect is somewhat stronger for small firms, compared to large firms, although both are statistically significant.

The results in Table 5 also indicate that productivity convergence is present in the data. The rate of productivity growth is increasing with the relative productivity gap between the firm and the (domestic-industry) frontier. For those firms with a large TFP gap relative to the frontier in the previous period (firms with low relative TFP), it is easier to imitate from others and therefore to catch up with the best firms over time. Similar evidence exists at the aggregate (Bond et al., 2001), industry (Griffith et al., 2003), and firm (Griffith et al., 2009) levels. According to the summary statistics in Table 3, the average productivity of non-frontier firms relative to the productivity frontier is 79 percent. For this average firm, and using the parameter estimates from regression 1 and the mean values for taxation and profitability, the rate of productivity growth would be 1.8 percentage points per annum faster than a firm with a productivity level of 85 percent of the frontier firm, and around 3.2 percentage points per annum faster than a firm with a productivity level of 90 percent of the frontier firm.14

There is also evidence in the table that higher taxation slows the rate of productivity catch-up for some firms. The TFP gap variable interacted with the corporate tax rate for all firms (TFP gap × CTax) is statistically significant and positive in regressions 1 and 2 but not regression 3. As a reminder, regression 2 restricts the sample to small firms only. In regression 3, where we restrict the sample to include firms with 20 or more employees (labelled large firms), the coefficient on the tax–TFP gap variable remains positive but is far from being significant at conventional levels. A test comparing the effect of taxation between small and large

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14These results relate to an “average” firm at a given distance from the frontier. Many additional factors are likely to affect the distribution of firms’ productivity catch-up around that average, such as variations in absorptive capacity or constraints on their ability to invest. Where this leads firms to exit their industry, it is likely to be imperfectly captured in the current dataset.
firms confirms this difference. These results are consistent with an interpretation that small firms are constrained in their ability to make PEIs and are therefore sensitive to corporate tax rates. The existing theoretical evidence suggests that this occurs because higher taxation reduces the net present value (NPV) of future investments for small firms, such that they invest less in productive technologies. Large firms are unaffected, possibly because the types of productivity investment they undertake are different from small firms, or because of better tax planning.

The effect of all this is to slow the rate of convergence of small firms, rather than to prevent it altogether, and within some countries small firms grow less quickly than large firms, despite typically having lower productivity. In countries such as Germany, the estimation results combined with the information in Table 3 indicate that the productivity differences between small and large firms, and between these firms and the productivity frontier, narrow over time: the rate of productivity catch-up for the average large firm (average TFP 94 percent of the frontier) would be 2.5 percent per annum, compared to 4.6 percent per annum for the average small firm (average TFP gap 83 percent of the frontier) when including the effects of taxation. This contrasts with countries where the initial TFP gap is much closer, such as Spain. Here the convergence-slowing effects of taxation are such that the productivity growth of small firms is below that of large firms. In these countries, small firms continue to catch up with the productivity frontier, but the average small and large firms are diverging from each other.

In Table 6, we provide further details on the magnitude of the tax effects, using 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 firm with a productivity level equal to 75, 85, and 95 percent of the frontier in their country at different rates of corporate taxation (25, 30, 35, 40, and 45 percent) compared to

15 We conduct this test by pooling small and large firms and by allowing the tax–TFP gap to differ between them (we also allow for differences in the rate of convergence). The coefficient for the effect of taxation for all firms is equal to 0.112 (standard error 0.109), while the estimated coefficient for the interaction of the tax-gap for small firms is 0.322 (standard error 0.111). Only the latter is significant, confirming a difference in the effect of taxation between small and large firms.

16 We consider the possibility that the results for taxation are affected by endogeneity bias by using an instrumental variable approach. The results from this exercise are reported as regression C3 in Online Appendix C, while further detail on their construction can be found in Online Appendix D. The results are robust to using this alternative estimation method.

17 This difference in the effect of taxation is of interest as it would suggest that in order for omitted variable bias to explain these findings, the omitted variable must be correlated with the convergence of small firms but not large firms. Whilst this can never be ruled out, it would at least appear to severely limit the possible candidates for such a variable.
### Table 6. Estimated effects of taxation on the productivity growth of small firms

| TFP (% of frontier) | Corporate tax rate |
|---------------------|-------------------|
|                     | 25%  | 30%  | 35%  | 40%  | 45%  | 75% |
| 75%                 | -0.43| -0.87| -1.30| -1.73| -2.17|
| 85%                 | -0.30| -0.60| -0.90| -1.20| -1.50|
| 95%                 | -0.19| -0.39| -0.58| -0.78| -0.97|

Notes: In this table we report how much more slowly firm productivity would be expected to grow relative to a firm that pays a 20 percent corporate tax rate and has the same TFP gap relative to the frontier. This table is based on the coefficient estimates from regression 2 (see Table 5).

A firm that faces a corporate tax rate of just 20 percent. 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 percent is close to that for Italy at the end of the sample period, whereas France had a tax rate of 35 percent by the end of the period, the UK around 30 percent, and Austria 25 percent. No country in our sample had a statutory corporate tax rate of 20 percent, 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 percent and with a productivity level of 75 percent of a frontier firm, productivity growth is 0.43 percentage points per annum slower compared with that for the same firm facing a corporate tax rate of 20 percent. In a high-tax country (where corporate tax rates are 40 percent), productivity growth is 1.73 percentage points slower than a firm facing a tax rate of 20 percent. The effects of taxation become quantitatively less important the closer the small firm is to the frontier. For firms with a productivity level equal to 95 percent of the frontier, operating in a low-tax environment (where the corporate tax rate is 25 percent compared to 20 percent), the difference is only 0.19 percentage points. From this, it would appear that differences in the size of the TFP gap matter more than differences in taxation for the growth rate of productivity in small firms, although both play a role.

**Robustness of Baseline Estimates**

In regressions 4–8 in Table 5 and in regressions 9 and 10 in Table 7, we establish the initial robustness of these findings. In regressions 4, 5, and 6, we redefine small firms as those with employment below 10, 30, and 50 employees, respectively. The results are very stable across these regressions, and indicate little sensitivity to this choice. We find consistent evidence that the rate of convergence for small firms is slowed.
Table 7. Robustness to inclusion of additional control variables and alternative tax variables

| Regression number | 9   | 10   | 11   | 12   | 13   |
|-------------------|-----|------|------|------|------|
| **TFP growth of frontier**<sub>jt</sub>\(x_1\) | 0.361*** | 0.634*** | 0.385*** | 0.377*** | 0.231*** |
| \(x_2\) | (0.007) | (0.007) | (0.006) | (0.006) | (0.008) |
| **TFP gap** | -0.456*** | -1.855*** | -0.740*** | -0.627*** | -0.982*** |
| \(x_3\) | (0.053) | (0.037) | (0.061) | (0.088) | (0.100) |
| **TFP gap x CTax**<sub>ct</sub> | 0.442*** | 2.727*** | 0.405*** |
| \(x_3\) | (0.102) | (0.112) | (0.146) |
| **TFP gap x Plnc.Tax**<sub>ct</sub> | 0.009*** | 0.010*** | 0.005*** |
| | (0.001) | (0.001) | (0.002) |
| **TFP gap x EMTR**<sub>ct</sub> | -0.173 | 2.691*** |
| | (0.224) | (0.275) |

Fiscal and profitability variables: ✓✓✓✓✓

\(\gamma_{C,j,t}\) ✓ ✓ ✓ ✓ ✓

Observations 183,569 183,569 175,847 175,847 41,937

Notes: The regressions are: 9–12, small firms; 13, large firms. See notes to Table 5. Regression 9 includes country–time and industry–time dummies as control variables. Regression 10 includes firm fixed effects. Regressions 11–13 include country, industry, and time dummies, and the personal income tax rate. Regressions 12 and 13 also include the effective marginal tax rate. *, **, and *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively.

by higher corporate tax rates, which are strongest when we concentrate on the smallest firms in regression 4.

In regressions 7 and 8, we test for the robustness of the results from regression 2 to alternative measures of TFP. As described in Section III, these use different methods to address the endogenous response of productivity to unobserved shocks. We report results using the methodologies of Olley and Pakes (1996) and Wooldridge (2009) for regressions 7 and 8, respectively. Using these alternative measures, we again find evidence that firms’ productivity growth is affected by the size of the productivity gap to the country–industry frontier and that the rate of catch-up is slower the higher the corporate tax rate is. The interaction between the productivity gap and the statutory corporate tax rate is again positive and statistically significant.

Other features of the policy environment, not accounted for in the regression, are a separate concern surrounding the effect of unobservable variables on the measurement of TFP. If these are correlated with taxation and affect the rate of productivity convergence across countries, then the estimates in Table 5 might be biased. In their empirical modelling, Arnold et al. (2011) control for time-varying country policy variables using country–time effects. In Table 7, regression 9, we follow this approach.
The inclusion of country– and industry–time dummies has little impact upon the results. The tax variable remains significant and positive.

A similar finding occurs when we include firm fixed effects in the model in regression 10. Thus far, we have assumed that the investments a firm makes in its productivity will move it closer to the domestic-industry frontier. Regression 10 relaxes this assumption and allows for the possibility that the returns to productivity enhancing investments might be constrained by difficult-to-observe, firm-specific characteristics, such as the managerial ability of the firm (Bloom and Van Reenen, 2007, 2010). Despite the change in modelling strategy, the key results remain unchanged. Higher corporate tax rates can slow the rate of productivity convergence. The magnitude of this effect is larger in this regression than previous estimates in the tables. This likely occurs because of the inclusion of firm fixed effects alongside the lagged dependent variable in the form of the measure of the TFP gap, which leads to a downward bias in the estimated coefficient on the lagged dependent variable (Nickell, 1981).

Additional Tax Variables

The review by Syverson (2011) makes clear that cross-firm differences in productivity are explained by a wide range of factors including the quality of machinery and equipment such as ICT, as well as human capital, R&D, and management or organizational differences. In our use of the statutory corporate tax rate, we have ignored the effect of deductions against taxable profits that can be made for capital investments (Devereux and Griffith, 2003) as well as the effect of personal income taxation on the efficiency of workers. This raises the question of whether an alternative measure of corporate taxation, such as the effective marginal tax rate, or other types of taxation, such as the personal income tax rate, are better able to capture the variation in productivity convergence that we focus on.

To model the effects of personal income taxation, we include an interaction between the top personal income tax rate and the productivity

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18 In regression C8 in the Online Appendix, we test whether omitted determinants of technological change within the firm might explain our findings by including intangible assets as a proxy for R&D. Despite a lack of information on intangible assets for many firms, our results are robust this. In Online Appendix E, we provide detail on the tax treatment of R&D across countries.

19 In regression 10, the coefficient on the TFP gap variable is larger than 1. However, at the mean value of profitability (26.7) and the mean value of corporate income taxation (0.35), the convergence parameter is equal to \[-0.759(-1.855 + (26.7 \times 0.0053) + (0.35 \times 2.727))\], confirming that the convergence path is not explosive.
Corporate taxation and productivity catch-up

gap variable in regression 11. In regression 12, we replace our measures of the statutory corporate tax rate with forward-looking effective rates based on the methodology of Devereux et al. (2002). Finally, in regression 13, we repeat regression 12 but consider only large firms.

We find some interesting results from this exercise. For personal income taxation, we find evidence that this also slows the rate of convergence, and the estimated coefficient is again positive and statistically significant. This occurs whether our focus is on small firms (regressions 11 and 12) or large firms (regression 13). We note, however, that there is some sensitivity of this finding in Table 8, where we find the reverse outcomes for personal income taxation. This indicates both that caution about the robustness of this finding is required and that further research is warranted.

For the effective corporate tax rate, we find there are differences in the effect between small and large firms. In regression 12, we find no effect from the effective marginal rate on small firms but there is an effect for large firms in regression 13. This evidence is consistent with Egger et al. (2014).

The 2001 German Tax Reforms as a Natural Experiment

As noted in the summary statistics in Section III, for most of the countries that make up our sample the rate of corporate taxation was reduced occasionally and in relatively small steps. The exception to this is Germany, where there was a large single reduction of just over 13 percentage points between 2000 and 2001. The key features of the reforms were the replacement of the different tax rates on retained earnings (40 percent) and distributed profits (30 percent) with a single lower tax on all profits (25 percent). When combined with local trading taxes, the statutory tax rate fell from 51.6 to 38.3 percent (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. They describe the motives behind this tax

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20 We thank the editor for this suggestion.

21 These results can also be seen to fit with a new but growing body of literature on the effects of personal taxes on corporate choices including location (e.g., Egger et al., 2013).

22 A possible reason why the effective marginal tax rate (EMTR) seems to be especially relevant to large firm’s TFP convergence could be related to large firms conducting more R&D. Where R&D expenditures involve investment in intangible capital, they will not generally be included in the Amadeus fixed capital data, and hence are contained within TFP estimates. Unfortunately, without data on R&D expenditures and the EMTRs applicable to them, we are unable to test how far R&D acts as a transmission mechanism from EMTRs to TFP. To the extent that EMTRs for equipment investment and EMTRs on R&D are correlated, our EMTR variable could be picking up both effects.

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Table 8. Corporate taxation and productivity convergence: German tax change

| Regression number | 14        | 15        | 16        | 17        | 18        | 19        |
|-------------------|-----------|-----------|-----------|-----------|-----------|-----------|
|                   | ESP, SWE, UK | ESP, SWE, UK | ESP, SWE, UK | ESP, SWE, UK | ESP, SWE, UK | ESP, SWE, UK |
| \( TFP \text{ growth of frontier}_{ct} (\beta_1) \) | 0.771*** | 1.003*** | 0.498*** | 0.773*** | 0.745*** | 0.752*** |
|                   | (0.011) | (0.026) | (0.018) | (0.013) | (0.012) | (0.013) |
| \( TFP \text{ gap} (\beta_2) \) | -1.833*** | -1.967*** | -1.370*** | -2.257*** | -1.498*** | -1.473*** |
|                   | (0.079) | (0.132) | (0.121) | (0.082) | (0.099) | (0.185) |
| \( TFP_{gap} \times \Delta C\text{Tax}_{ct} (\beta_3) \) | 2.555*** | 0.699*** | 1.781*** | 2.583*** | 2.679*** | 1.942*** |
|                   | (0.362) | (0.259) | (0.248) | (0.392) | (0.363) | (0.337) |
| \( TFP_{gap} \times C\text{Tax}_{1999} (\beta_4) \) | 2.770*** | 2.251*** | 2.261*** | 3.535*** | 4.380*** | 4.547*** |
|                   | (0.162) | (0.267) | (0.147) | (0.216) | (0.356) | (0.437) |
| \( TFP_{gap} \times P\text{Inc.Tax}_{ct} \) | \( -0.022*** \) | \( -0.021*** \) | | | | |
|                   | \( (0.004) \) | \( (0.004) \) | | | | |
| \( TFP_{gap} \times EMTR_{ct} \) | | | | | \( -0.517 \) | \( (0.73) \) |
| Observations | 37,888 | 21,189 | 23,982 | 32,042 | 37,888 | 37,888 |

Notes: See notes to Table 5. All regressions include firm and year fixed effects. Regression 15 repeats 14 but collapses the data to a single pre-treatment (1999–2000) and post-treatment (2001–2002) period. Regressions 16 and 17 exclude UK and Swedish firms, respectively, from the counterfactual. Regressions 18 and 19 use the same sample as regression 14 but include a measure of the personal income tax rate and the effective marginal tax rate, respectively. In the control groups, SWE denotes small firms from Sweden, ESP denotes firms from Spain, and UK denotes firms from the UK. Small German firms (the treatment group) are included in all regressions. *, **, and *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively.
Corporate taxation and productivity catch-up

reform as aimed at attracting foreign direct investment, and adapting 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 particular for small firms.23

Equation (2), which forms the model for estimation in this section, considers whether the corporate tax reforms affected productivity growth of small German firms compared to the pre-reform period (1999–2000). These growth effects are compared to a counterfactual of firms from Spain, Sweden, and the UK. Small firms from these countries are chosen because the corporate tax rates remained unchanged in these countries over the years 1999–2002, whereas they changed in all other European countries.24

Invariably difference-in-difference regression estimates are scrutinized over the extent to which the control group represents the valid counterfactual. What would have happened in the absence of the tax reforms? To determine this, we test whether productivity growth amongst small German firms was significantly different than that of small firms from Spain, Sweden, and the UK in 1999 or 2000, conditional on the size of their initial TFP gap and any movements in the frontier. We find that we cannot reject the null that the productivity growth rates were the same in the two groups; the \( t \)-statistic is equal to 0.01. The parallel trend assumption would therefore appear to be satisfied.

Both of the tax variables have positive and statistically significant coefficients in regression 14. Holding constant the tax rate across time, we find that firms that face higher tax rates grow less quickly for the same relative productivity (\( \beta_4 \) is positive). This mirrors the findings in Tables 5 and 7 regarding the effects of taxation on the productivity growth of small firms. We also find additional effects from the tax reforms in Germany. Specifically, the results show that productivity within small German firms grew more quickly relative to the counterfactual in the period following the corporate tax reforms in Germany. Again, this effect is increasing with the size of the productivity gap (\( \beta_3 \) is positive).

Bertrand et al. (2004) note that a consequence of using difference-in-difference estimates with data spanning several years, and where outcomes

23 Our results in the previous sections of the paper are not dependent on the inclusion of Germany and, therefore, this large tax event in the data. Excluding Germany (see regression C6 in Online Appendix C), the results are unchanged.

24 The differences in the effect of corporate taxation between small and large firms reported in Tables 5 and 7 suggest that large firms might also represent a valid counterfactual, as they are unaffected by statutory corporate tax rates. We report regressions using large German firms as the counterfactual in Table C2 (regressions C9–C11) in Online Appendix C. We continue to find that the productivity growth of small firms increased as a consequence of the reduction in tax rates.

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are serially correlated, is that the estimated standard errors will be inconsistent, resulting in spurious inference. One solution suggested by Bertrand et al. (2004) is to collapse the data into a single pre- and post-treatment time period. We conduct this robustness test in regression 15, which accounts for the fall in the number of observations within the table compared to regression 14. The pre-treatment period is defined as the years 1999 and 2000 while the post-treatment period is the years 2001 and 2002. Although the standard errors are somewhat larger when we use this approach, our results remain robust and highly significant.25

How large are the effects that we estimate? Using the 13 percentage point reduction in corporate tax rates and the coefficient estimates from regression 15, our results suggest that for a small firm with a TFP level of 85 percent (90 percent) of the frontier firm, TFP growth was 1.5 (1.0) percentage points higher compared to that if corporate tax rates were left at 51 percent.

In the remaining regressions of Table 8, we try to further establish the robustness of these findings, in particular to the effect of other tax changes. The counterfactual countries were chosen as they included no changes to corporate tax rates between 1999 and 2002. However, corporate tax rates were reduced in the UK in 1998, and there were changes in personal income tax rates in Germany and Sweden. In Germany, the top rate of personal income tax was reduced from 53 percent in 1999 to 51 percent in 2000, and again in 2001 to 48.5 percent, while in Sweden it was reduced from 31 to 25 percent between 1999 and 2000. There were also changes to the effective marginal corporate tax rate in Germany over this period, which fell by 9.3 percentage points between 1999 and 2000, and rose by 4.2 percentage points between 2000 and 2001. There were no changes to the effective marginal rate for Spain or Sweden, and a small decrease of 0.7 percentage points between 1999 and 2000 in the UK.

To ensure that the effects of the changes to personal or effective marginal corporate tax rates do not contaminate our results in regression 16, we exclude UK firms from the counterfactual, and in regression 17 we exclude Sweden on the basis there was a change in the personal income tax rate. In regressions 18 and 19, we take a different approach to this issue and instead add measures of personal income tax rates (regressions 18 and 19) and the effective marginal rate (regression 19) used previously in regressions 11–13 in Table 7. Our main variables of interest are unaffected by controlling for other tax events in either the treatment country (Germany) or the counterfactual (Spain, Sweden, and

25 There are 2,336 observations for German firms before 2000, 2,596 in 2001, and 2,808 in 2002.
the UK). In all of the regressions, we find that the reductions in the corporate tax rate in Germany increase productivity growth for small German firms.26

V. Conclusions

The role that government plays in encouraging productivity growth in firms has always attracted considerable academic interest. However, much of this interest has 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 country – the role of corporate taxation. The idea that taxation might affect productivity is not new, but its effects have typically only been examined as an indirect consequence of physical (tangible) capital or R&D investments. In this paper, we provide evidence on whether corporate marginal tax rates affect 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 PEIs. These results appear very robust to the addition of covariates to the regression, including those that account for differences in the steady-state level of productivity of firms. They are also robust to 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 they 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. This highlights an important heterogeneity in the effects of taxation across countries, due to differences in the level of taxation, the number of smaller firms, and the size of the TFP gap with the productivity frontier.

While a country’s corporate tax policy is, and should be, influenced by numerous considerations, an important implication for corporate tax policy to emerge from this paper concerns the use of different statutory

26 In an unreported regression, we ran a placebo test that restricted the sample window to 1999 and 2000. We then created a placebo treatment (equal to 1 in 2000, and 0 in 1999) and interacted this with the TFP gap variable. The coefficient on the interaction was insignificant, indicating no pre-treatment trends or anticipation effects. We are unaware of any other non-tax policy changes that differ between Germany and the counterfactual countries over this period. The non-adoption of the euro by the UK in 1999 might have had some lagged effects on TFP compared to the other three countries, but such effects, if they existed, seem likely to be minor for our results.
corporate rates for small firms versus large firms. In the UK and in Spain, for example, the recent policy shift towards harmonization of corporate tax rates between small and large firms (from a regime in which small firms faced lower rates) could adversely affect the ability of smaller firms to catch up on the productivity frontier.

Supporting Information
The following supporting information can be found in the online version of this article at the publisher’s web site.

Online Appendix

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